Geo Duffield

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PHYSICO AND ASTRO THEOLOGY;

OR, A

DEMONSTRATION

OF

The Being and Attributes of God.

A NEW EDITION

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A SURVEY OF QUADRUPEDS.

CHAP. I.

OF THEIR PRONE POSTURE.

IN taking a view of this part of the animal world, ſo far as the ſtructure of their bodies is conformable to that of man, I ſhall paſs them by, and only take notice of ſome peculiarities in them, which are plain indications of deſign, and the divine ſuperintendence and management. And, 1, The moſt viſible apparent variation is the prone poſture of their body: concerning which I ſhall take notice only of two things, the parts miniſtring thereto, and the uſe and benefit thereof.

I. As for the parts, it is obſervable, that in all theſe creatures, the legs are made exactly conformable to this poſture, as thoſe in man are to his erect poſture: and what is farther obſervable alſo, is, that the legs and feet are always admirably ſuited to the motion and exerciſes of each animal: in ſome they are made for ſtrength only, to ſupport a vaſt, unwieldy body [a]; in others they are made for agility and ſwiftneſs [b], in ſome they are made for only walking and running

[a] The elephant being a creature of prodigious weight, the largeſt of all animals, Pliny ſaith, hath its legs accordingly made of an immenſe ſtrength, like pillars, rather than legs.

[b] Deer, hares, and other creatures, remarkable for ſwiftneſs, have the legs accordingly ſlender, but withal ſtrong, and every way adapted to their ſwiftneſs.

[c] Thus the feet of the otter are made, the toes being all conjoined with membranes, as the feet of geeſe and ducks are. And in ſwimming it is obſervable, that when the foot goes forward in the water, the toes are cloſe; but when backward, they are ſpread out, whereby they more forcibly ſtrike the water, and drive themſelves forward. The ſame may be obſerved alſo in ducks and geeſe, &c.

Of the caſtor or beaver, the French academiſts ſay, 'The ſtructure of the feet was very extraordinary, and ſufficiently demonſtrated, that nature hath deſigned this animal to live in the water, as well as upon land. For although it had four feet, like terreſtrial animals, yet the hindmoſt ſeemed more proper to ſwim than walk with, the five toes of which they are compoſed, being joined together like thoſe of a gooſe by a membrane, which ſerves this animal to ſwim with. But the fore ones were made other-

 wiſe;

running, in others for that, and ſwimming too [c]; in others for walking and digging [d]; and in others for walking and flying [e]: in ſome they are made more laſk and weak, for the plainer lands; in others rigid, ſtiff, and leſs flexible [f], for traverſing the ice, and dangerous precipices of the high mountains [g]; in ſome they are ſhod with

'wiſe; for there was no membrane, which held theſe toes joined 'together; and this was requiſite for the conveniency of this animal, which uſeth them as hands like a ſquirrel, when he eats.' Memoirs for a Natural Hiſtory of Animals, p. 84.

[d] The moles feet are a remarkable inſtance.

[e] The wings of the bat are a prodigious deviation from nature's ordinary way. So it is in the virginian ſquirrel, whoſe ſkin is extended between the fore-legs and its body.

[f] Of the legs of the elk, the French academiſts ſay. 'Although ſome authors report, that there are elks in Muſcovia, 'whoſe legs are jointleſs; there is great probability, that this opinion is founded on what is reported of thoſe elks of Muſcovia, as 'well as of Cæſar's Alce, and Pliny's Machlis, that they have legs 'ſo ſtiff and inflexible, that they do run on ice without ſlipping; 'which is a way that is reported that they have to ſave themſelves from the wolves,' &c. p. 108.

[g] The common tame goat (whoſe habitation is generally on mountains and rocks, and who delighteth to walk on the tops of pales, houſes, &c. and to take great and ſeemingly dangerous leaps) I have obſerved, hath the joints of the legs very ſtiff and ſtrong, the hoof hollow underneath, and its edges ſharp. The like, I doubt not, is to be found in the wild goat, conſidering what Dr. Scheuchzer hath ſaid of its climbing the moſt dangerous craggs of the Alps, and the manner of their hunting it. Vide Iter Alpin 3. p. 9.

rough and hard hoofs, ſome whole, ſome cleft; in others with only a callous ſkin. In which latter, it is obſervable that the feet are compoſed of toes, ſome ſhort for bare-going; ſome long to ſupply the place of a hand [h]; ſome armed with long and ſtrong talons to catch, hold, and tear the prey; ſome fenced only with ſhort nails, to confirm the ſteps in running and walking.

II. As the poſture of man's body is the fitteſt for a rational animal, ſo is the prone poſture of quadrupeds, the moſt uſeful and beneficial to themſelves, as alſo moſt ſerviceable to man. For they are hereby better made for their gathering their food, to purſue their prey, to leap, to climb, to ſwim, to guard themſelves againſt their enemies; and, in a word, to do whatever may be of principal uſe to themſelves; as alſo they are hereby rendered more uſeful and ſerviceable to man for carrying his burdens, for tilling his ground; yea, even for his ſports and diverſions.

And now I might here add a ſurvey of the excellent contrivance of the parts miniſtring to this poſture of the four-footed animals, the admirable

[h] Thus in apes and monkeys, in the beaver before, and divers others.

mirable ſtructure of the bones[i], the joints and muſcles, their various ſizes and ſtrength; their commodious lodgment and ſituation, the nice æquipoiſe of the body, with a great deal more to the ſame purpoſe. But I ſhould be tedious to inſiſt minutely upon ſuch particulars; and beſides, I have given a touch upon theſe kind of things, when I ſpake of man.

Paſſing by therefore many things of this kind, that might deſerve remark, I ſhall only conſider ſome of the parts of quadrupeds, differing from what is found in man[k], and which are manifeſt works of deſign.

[i] It is a ſingular proviſion nature hath made for the ſtrength of the lion, if that be true, which Galen ſaith is reported of its bones being not hollow, as in other animals, but ſolid: which report he thus far confirms, that moſt of the bones are ſo; and that thoſe in the legs; and ſome other parts, have only a ſmall and obſcure cavity in them. Vide Galen. de uſu Part I. 11. c. 18.

[k] 'Theſe ſorts of differences in the mechaniſm of animals, 'upon the ſcore of the poſition of their bodies, occur ſo often, 'that it would be no mean ſervice to anatomy—if any one would 'give us a hiſtory of thoſe variations of the parts of animals, which 'ſpring from the different poſtures of their bodies.' Drake Anat. vol. 1. Book 1. chap. 17.

CHAP. II.

OF THE HEADS OF QUADRUPEDS.

IT is remarkable that, in man, the head is of one ſingular form; in the four-footed race, as various as their ſpecies. In ſome, ſquare and large, ſuitable to their ſlow motion, food, and abode; in others leſs, ſlender, and ſharp, agreeable to their ſwifter motion, or to make their way to their food [l], or habitation under ground [m]. But paſſing by a great many obſervations that might be made of this kind, I ſhall ſtop a little

[l] Thus ſwine, for inſtance, who dig in the earth for roots, and other food, have their neck, and all parts of their head very well adapted to that ſervice. Their neck ſhort, brawny and ſtrong; their eyes ſet pretty high out of the way; their ſnout long; their noſe callous and ſtrong; and their ſenſe of ſmelling very accurate, to hunt out and diſtinguiſh their food in mud, under ground, and other the like places where it lies concealed.

[m] What hath been ſaid of ſwine is no leſs, rather more remarkable in the mole, whoſe neck, noſe, eyes, and ears, are all fitted, in the niceſt manner, to its ſubterraneous way of life.

at

at the brain; as the moſt conſiderable part of the body, being the great inſtrument of life and motion in quadrupeds, as it is in man of that, as alſo in all probability the chief ſeat of his immortal ſoul. And accordingly it is a remarkable difference, that in man the brain is large, affording ſubſtance and room for ſo noble a gueſt; whereas in quadrupeds, it is but ſmall. And another thing, no leſs remarkable, is the ſituation of the cerebrum and cerebellum, or the greater and leſſer brain, which I ſhall give in the words of one of the moſt exact anatomiſts we have of that part [a]: 'Since, ſaith he, God hath given 'to man a lofty countenance, to behold the 'heavens, and hath alſo ſeated an immortal ſoul 'in the brain, capable of the contemplation of 'heavenly things; therefore, as his face is 'erect, ſo the brain is ſet in an higher place, 'namely, above the cerebellum, and all the ſenſories. But in brutes, whoſe face is prone towards the earth, and whoſe brain is incapable 'of ſpeculation, the cerebellum, (whoſe buſineſs it is to miniſter to the actions and functions 'of the præcordia, the principal office in thoſe 'creatures) in them is ſituated in the higher 'place, and the cerebrum lower. Alſo ſome of 'the organs of ſenſe, as the ears and eyes, are 'placed,

[a] Willis Cereb. Anat. cap. 6. 'Cumque huic Deus os ſublime dederit.' &c.

'placed, if not above the cerebrum, yet at leaſt 'equal thereunto.'

Another convenience in this poſition of the cerebrum and cerebellum, the laſt ingenious anatomiſt tells us is this [o]. 'In the head of man,' ſaith he, 'the baſe of the brain and cerebell, 'yea, of the whole ſkull, is ſet parallel to the 'horizon; by which means there is the leſs dan- 'ger of the two brains joggling, or ſlipping out 'of their place. But in quadrupeds, whoſe 'head hangs down, the baſe of the ſkull makes 'a right angle with the horizon, by which 'means the brain is undermoſt, and the cerebell 'uppermoſt; ſo that one would be apt to ima- 'gine the cerebell ſhould not be ſteady, but 'joggle out of its place.' To remedy which in- convenience, he tells us, 'And leſt the frequent 'concuſſions of the cerebell ſhould cauſe a faint- 'ing, or diſorderly motion of the ſpirits, about 'the præcordia, therefore, by the artifice of na- 'ture, ſufficient proviſion is made in all, by the 'dura meninx cloſely encompaſſing the cerebel- 'lum; beſides which, it is, in ſome, guarded 'with a ſtrong bony fence; and in others, as the 'hare, the coney, and ſuch leſſer quadrupeds, a 'part of the cerebell is on each ſide fenced with the

[o] Id. paulo poſt. 'In capite humano cerebri et cerebelli,' &c.

'the os petrosum: so that by this double stay, 'its whole mass is firmly contained within the 'skull.'

Besides these peculiarities, I might take notice of divers other things no less remarkable, as the nictating membrane of the eye[p], the different passages of the carotid arteries[r] through the skull

[p] See book iv. chap. 2.

[r] 'Arteria carotis aliquanto posterius in homine quam in alio 'quovis animali, calvariam ingreditur, scil. juxta illud foramen, 'per quod sinus lateralis in venam jugularem desiturus crano elabi-'tur: nam in cæteris hæc arteria sub extremitate seu processu 'acuto ossis petrosi, inter cranium emergit; verum in capite hu-'mano, eadem, ambage longiori circumducta (ut sanguinis torrens, 'priusquam ad cerebri oram apellit, fracto impetu, lenius et placi-'dius fluat) prope specum ab ingressu sinus lateralis factum, cal-'variæ basin attingit;—et in majorem cautelam, tunica insuper 'ascititia crassiore investitur.' And so he goes on to shew the con veniency of this guard the artery hath, and its passage to the brain, and then saith, 'Si hujusmodi conformationis ratio inquiritur, facile 'occurrit, in capite humano, ubi generosi affectus et magni animo-'rum impetus ac ardores excitantur, sanguinis in cerebri oras ap-'pulsum debere esse liberum et expeditum, &c. Atque hoc quidem 'respectu differt homo a plerisque brutis, quibus, arteria in mille 'surculos divisa, ne sanguinem pleniore alveo, aut citatiore, quam 'par est, cursu, ad cerebrum evehat, plexus retiformes constituit, 'quibus nempe efficitur, ut sanguis tardo admodum, lenique et 'æquabili fere stilicidio, in cerebrum illabatur.' And then he goes on to give a farther account of this artery, and the rete mirabile, in divers creatures. Willis, ibid. c. 8.

ſkull, their branching into the rete mirabile [r], the different magnitude of the nates, and ſome other parts of the brain in beaſts, quite different from what it is in man: but the touches already given, may be inſtances ſufficient to prevent my being tedious in enlarging upon theſe admirable works of God.

[r] Galen thinks the rete mirabile is for concocting and elaborating the animal ſpirits, as the epididymes, (the convolutions, κιρσοειδὴς ἕλικος] are for elaborating the ſeed, De uſu Part. l. ix. c. 4. This rete is much more conſpicuous in beaſts than man: and, as Dr. Willis well judges, ſerves, 1. To bridle the too rapid incurſions of the blood into the brain of thoſe creatures, whoſe heads hang down much. 2. To ſeparate ſome of the ſuperfluous ſerous parts of the blood, and ſend them to the ſalival glands, before the blood enters the brain of thoſe animals, whoſe blood is naturally of a watery conſtitution. 3. To obviate any obſtructions that may happen in the arteries, by giving a free paſſage through other veſſels, when ſome are ſtopped.

In quadrupeds, as the carotid arteries are branched into the rete mirabile, for the bridling the too rapid current of blood into the brain; ſo the vertebral arteries are, near their entrance into the ſkull, bent into an acuter angle than in man, which is a wiſe proviſion for the ſame purpoſe.

CHAP.

CHAP. III.

OF THE NECKS OF QUADRUPEDS.

FROM the head paſs we to the neck, no principal part of the body, but yet a good inſtance of the Creator's wiſdom and deſign, inaſmuch as in man it is ſhort, agreeable to the erection of his body; but in the four-footed tribe it is long, anſwerable to the length of the legs, * and in ſome of theſe long, and leſs ſtrong, ſerving

* It is very remarkable, that in all the ſpecies of quadrupeds, this equality holds, except only the elephant; and that there ſhould be a ſufficient ſpecial proviſion made for that creature, by its proboſcis or trunk. A member ſo admirably contrived, ſo curiouſly wrought, and with ſo great agility and readineſs applied by that unweildly creature to all its ſeveral occaſions, that I take it to be a manifeſt inſtance of the Creator's workmanſhip. See its anatomy in Dr. A. Moulen's Anat. of the Elephant, p. 33. As alſo in Mr. Blair's account in Phil. Tranſ. No. 326.

' Aliorum ea eſt humilitas, ut cibum terreſtrem roſtris facile contingant. Quæ autem altiora ſunt, ut anſeres, ut cygni, ut grues, ' ut ving to carry the mouth tothe ground; in others ſhorter, brawny, and ſtrong, ſerving to dig, and heave up great burdens [t].

But that which deſerves eſpecial remark is, that peculiar proviſion made in the necks of all, or moſt granivorous quadrupeds, for the perpetual holding down their heads in gathering their food, by that ſtrong, tendinous, and inſenſible aponeuroſis or ligamen [u], braced from the head to the middle of the back. By which means the head, although heavy, may be long held down without any labour, pain, or uneaſineſs to the muſcles of the neck, that would otherwiſe be wearied by being ſo long put upon the ſtretch.

' ut cameli, adjuvantur proceritate collorum. Manus etiam data ' elephantis, qui propter magnitudinem corporis difficiles aditus ha' bebant ad paſtum.' Cic. de Nat. Deor. l. ii. c. 47.

' Quod iis animalibus quæ pedes habent fiſſos in digitos, collum ' brevius ſit factum, quam ut per ipſum cibum ori admovere queant: ' iis vero quæ ungulas habent ſolidas, aut bifidas, longius, ut prona ' atque inclinantia paſci queant. Qui id etiam opus non ſit artificis ' utilitatis memoris? Ad hæc quod grues ac ciconiæ, cum crura habe' rent longiora, ob eam cauſam roſtrum etiam magnum, et collum lon' gius habuerint. Piſces autem neque collum penitus habuere, ut' pote qui neque crura habent. Quo pacto non id etiam eſt admi' randum?' Galen. de uſu Part. l. xi. c. 8.

[t] As in moles and ſwine, in chap. ii. note p.

[u] Called the white-leather, pack-wax, tax wax, and fix-fax.

CHAP.

CHAP. IV.

OF THE STOMACHS OF QUADRUPEDS.

FROM the neck, let us defcend to the Stomach, a part as of abfolute neceffity to the being and well-being of animals, fo is in the feveral fpecies of quadrupeds, fixed, contrived, and made with the utmoft variety and art [v]. What artift, what being, but the infinite confervator of the world, could fo well adapt every food to all the feveral kinds of thofe grand devourers of

[v] THE peculiar contrivance and make of the dromedary's or camel's ftomach, is very remarkable, which I will give from the Parifian anatomifts: 'At the top of the fecond (of the four ventricles) 'there were feveral fquare holes, which were the orifices of about 'thirty cavities, made like facks placed between the two membranes, 'which do compofe the fubftance of this ventricle. The view of thefe facks made us to think that they might well be the refervatories, where Pliny faith, that camels do a long time keep the water, which they drink in great abundance——to fupply the wants thereof in the dry defarts,' &c. Vide Memoirs, &c. Anat. of Dromedary, p. 39. See alfo Peyer. Merycol. l. 2. c. 3.

of it; Who could ſo well ſuit their ſtomachs to the reception and digeſtion thereof; one kind of ſtomach to the carnivorous, another to the herbacious animals: one fitted to digeſt by bare maſtication: and a whole ſet of ſtomachs in others, to digeſt with the help of rumination! Which laſt act, together with the apparatus for that ſervice, is ſo peculiar, and withal ſo curious an artifice of nature, that it might juſtly deſerve a more particular inquiry; but having formerly mentioned it[w], and leſt I ſhould be too tedious, I ſhall paſs it by.

[w] Book iv. chap. 11.

CHAP.

CHAP. V.

OF THE HEARTS OF QUADRUPEDS.

IN this part is a notable difference found between the heart of man and that of beasts; concerning the latter of which I might take notice of the remarkable conformation of the hearts of amphibious quadrupeds, and their difference from those of land-animals, some having but one ventricle [x], some three [z], and some but two, like land-animals, but then the foramen ovale therewith

[x] Frogs are generally thought to have but one ventricle in their hearts.

[z] The tortoise hath three ventricles, as the Parisian academists in their Memoirs affirm. 'Besides those two ventricles [before 'spoken of] which were in the hinder part of the heart, which 'faceth the spine, there was, say they, a third in the fore-part, in'clining a little towards the right side,' &c. Memoirs, &c. p. 259. But Mr. Bussiere charges this as a mistake in those ingenious gentlemen, and asserts there is but one ventricle in the tortoise's heart. See his description of the heart of the land-tortoise, in Philos. Trans. N° 328.

therewith [a]. All which may be juſtly eſteemed as wonderful, as they are excellent proviſions for the manner of thoſe animals living, But I ſhall content myſelf with bare hints of theſe things, and ſpeak only of two peculiars more, and that but briefly.

One is, the ſituation of the heart, which in beaſts is near the middle of the whole body; in man, nearer the head [b]. The reaſons of which I ſhall give from one of the moſt curious anatomiſts of that part [c]. 'Seeing, ſaith he, the trajection and diſtribution of the blood depends 'wholly on the ſyſtole of the heart, and that its 'liquor is not driven of its own nature ſo readily 'into the upper parts as into veſſels even with it, 'or downwards into thoſe under it; if the ſituation

[a] THE ſea-calf is ſaid by the French academiſts, to have this proviſion, and their account of it is this: 'Its heart was round 'and flat. Its ventricles appeared very large, and its auricles 'ſmall.———Underneath the great aperture, through which 'the trunk of the vena cava conveyed the blood into the right ven'tricle of the heart, there was another, which penetrated into the 'arteria venoſa, and from thence into the left ventricle, and after'wards into the aorta. This hole, called the foramen ovale in the 'foetus, makes the anaſtomoſis, by the means of which, the blood 'goes from the cava into the aorta, without paſſing through the 'lungs.' French Anat. p. 124.

[b] Τὴν τε Καρδίαν περὶ τὸ μέσον πλὴν ἐν Ανθρώπῳ, &c. Ariſto Hiſt. An. l. ii. c. 17.

[c] DR. Lower de Corde, c. 1.

'tion of the heart had been farther from the 'head, it muſt needs either have been made 'ſtronger, to caſt out its liquor with greater 'force; or elſe the head would want its due 'proportion of blood. But in animals that 'have a longer neck, and which is extended 'towards their food as it were, the heart is 'ſeated as far from the other parts; and they 'find no inconvenience from it, becauſe they 'feed with their head for the moſt part hanging 'down; and ſo the blood, as it hath farther to go 'to their head than in others, ſo it goes a plainer 'and often a ſteep way [c].

The other peculiar matter is, the faſtening, I formerly mentioned, which the cone of the pericardium hath in man to the diaphragm [d], whereas in all quadrupeds it is looſe. By which

[c] I might have mentioned another wiſe proviſion from the ſame author, which take in his own words: 'In vitulis et equis, imo 'pleriſque aliis animalibus majoribus, non ſolas propagines a nervo 'ſexti paris ut in homine, ſed etiam plurimum a nervo intercoſtali, 'ubi recta cor tranſit, cor accedere, imo in parenchyma ejus dimitti: 'et hoc ideo a natura quaſi ſubſidium brutis comparatum, ne capita 'quæ terram prona ſpectant, non ſatis facile aut copioſe ſpiritus 'animales impertirent.' Blaſii Anat. Animal. par. i. c. 4. ex Lowero, de corde.

[d] 'Diaphragmatis circulo nerveo firmiter adhæret (pericardium) 'quod homini ſingulare; nam ab eo in canibus et ſimiis diſtat, 'item in aliis animalibus omnibus.' Bartholin. Anat. l. ii. c. 5.

means the motion of the midriff, in that necessary act of respiration, is assisted both in the upright posture of man, as also in the prone posture of quadrupeds [e], which would be hindered, or rendered more difficult, if the case was otherwise: 'Which must needs be the effect of wisdom and 'design, and that man was intended by nature to 'walk erect, not upon all-four, as quadrupeds 'do; to express it in the words of a great judge 'in such matters [f].

[e] 'Finalem causam quod attinet,——cum erectus sit hominis incessus atque figura, eoque facilius abdominis viscera suo pondere 'descendant, minore diaphragmatis nixu atque systole ad inspirationem opus est: porro, cum in expiratione pariter necessarium 'sit diaphragma relaxari,— cum capsula cordis omnino connectendum fuit, in homine, ne forte, quamdiu erectus incedit, ab hepatis, 'aliorumque viscerum appensorum pondere deorsum adeo deprimeretur, ut neque pulmo satis concidere, neque expiratio debito 'modo peragi potuerit. Quocirca in quadrupedibus, ubi abdominis viscera in ipsum diaphragma incumbunt, ipsumque in pectoris 'cavitatem suo pondere impellunt, ista partium accretio expirationi 'quidem inutilis, inspirationi autem debitam diaphragmatis tensionem impediendo, prorsus incommoda fuisset.' Lower, ib. p. 81

[f] Dr. Tyson's Anatomy of the Orang-Outang, in Ray's Wisdom of God, p. 262.

CHAP.

CHAP. VI.

OF THE DIFFERENCE BETWEEN MAN AND QUADRUPEDS IN THE NERVOUS KIND.

THERE is only one difference more between man and quadrupeds that I ſhall take notice of, and that is the nervous kind; and becauſe it would be tedious to inſiſt upon many particulars [g], I ſhall, for a ſample, inſiſt chiefly upon one, and that is, of nature's prodigious care for a due communication and correſpondence between the head and heart of man, more than what is in the four-footed tribe. For this purpoſe, beſides the correſpondence thoſe parts have by means of the nerves of the par vagum, common both to

(g) AMONG theſe, I might name the ſeat of the nerves proceeding from the medulla ſpinalis, which Dr. Lower takes notice of. In beaſts, whoſe ſpine is above the reſt of the body, the nerves tend directly downwards; but in man, it being erect, the nerves ſpring out of the ſpine, not at right, but in oblique angles downwards, and paſs alſo in the body the ſame way. Ib. p. 16.

man and beaſt, there is a farther and more ſpecial communication and correſpondence occaſioned by the branches[h] of the intercoſtal pair, ſent from the cervical plexus to the heart, and præcordia. By which means the heart and brain of man have a mutual and very intimate correſpondence and concern with each other, more than is in other creatures; or as one of the moſt curious anatomiſts and obſervers of theſe things ſaith[i]: 'Brutes are as it were machines made with a ſimpler and leſs operoſe apparatus, and endowed 'therefore with only one and the ſame kind of 'motion, are determined to do the ſame thing: 'whereas in man, there is a great variety of 'motions and actions. For by the commerce 'of the aforeſaid cervical plexus[k], he ſaith, the con-

[h] 'In pleriſque brutis tantum hac via (i. e. by the par vagum) et 'vix omnino, per ullos paris intercoſtalis nervos, aditus ad cor aut 'appendicem ejus pateſcit. Verum in homine, nervus intercoſtalis, 'præter officia ejus in imo ventre huic cum cæteris animalibus com'munia, etiam ante pectoris clauſtra internuntii ſpecialis loco eſt, 'qui cerebri et cordis ſenſa mutua ultra citraque refert.' Willis Nervor. Deſcr. et Uſus, c. 26.

[i] Id. ib. 'Dum hanc utriuſque ſpeciei differentiam perpendo, 'ſuccurrit animo, bruta eſſe velut machinas,' &c.

That our great man was not miſtaken, there is great reaſon to imagine, from what he obſerved in diſſecting a fool. Beſides the brain being but ſmall, he ſaith, 'Præcipua autem diſcriminis 'nota quam, inter illius et viri cordati partes advertimus, hæcce 'erat;

'conceptions of the brain presently affect the 'heart, and agitate its vessels and whole appen'dage, together with the diaphragm. From 'whence the alteration in the motion of the 'blood, the pulse, and respiration. So also, on 'the contrary, when any thing affects or alters 'the heart, those impressions are not only re'torted to the brain by the same duct of the 'nerves, but also the blood itself, its course 'being once changed, flies to the brain with a 'different and unusual course, and there agitat'ing the animal spirits with divers impulses, 'produceth various conceptions and thoughts in 'the mind.' And he tells us, 'That hence it 'was, that the ancient divines, and philosophers 'too, made the heart the seat of wisdom; and, 'certainly, says he, the works of wisdom and 'virtue do very much depend upon this com'merce which is between the heart and brain:" and so he goeth on with more to the same purpose. Upon the account of this intercostal commerce with the heart being wanting in brutes, there is another singularly careful and wise provision the infinite Creator hath made in them, and that is, that by reason both the par vagum, and

'erat; nempe quod prædictus nervi intercostalis plexus, quem 'cerebri et cordis internuncium et hominis proprium diximus, in 'stulto hoc, valde exilis, et minori nervorum satellitio stipatus 'fuerit.' Ibid.

the intercoſtal too, do not ſend their branches to the heart, and its appendage in brutes; therefore, leſt their heart ſhould want a due proportion of nervous veſſels, the par vagum ſends more branches to their heart than to that of man. This, as it is a remarkable difference between rational and irrational creatures; ſo it is as remarkable an argument of the Creator's art and care; who, although he hath denied brute-animals reaſon, and the nerves minſtering thereto, yet hath another way ſupplied what is neceſſary to their life and ſtate. But let us hear the ſame great author's deſcant upon the point[1]. 'Inaſmuch, ſaith he, 'as beaſts are void of diſcretion, and but little 'ſubject to various and different paſſions, there'fore there was no need that the ſpirits, that 'were to be conveyed from the brain to the 'præcordia, ſhould paſs two different ways, 'namely, one for the ſervice of the vital func'tions, and another for the reciprocal impreſſi'ons of the affections; but it was ſufficient that 'all their ſpirits, whatever uſe they were deſign'ed for, ſhould be conveyed one and the ſame 'way.'

[1] Id. ib. chap. 29. 'In quantum beſtiæ prudentia carent, et variis 'diverſiſque paſſionibus,' &c.

HERE

Here now in the nervous kind we have manifeſt acts of the Creator's deſign and wiſdom, in this ſo manifeſt and diſtinct a proviſion for rational and irrational creatures; and that man was evidently intended to be the one, as the genus of quadrupeds was the other.

CHAP. VII.

THE CONCLUSION.

AND now it is time to paufe a while, and reflect upon the whole. And as from the confiderations in the preceding book, we have efpecial reafon to be thankful to our infinitely merciful Maker, for his no lefs kind than wonderful contrivances of our body; fo we have reafon, from this brief view I have taken of this laft tribe of the creation, to acknowledge and admire the fame Creator's work and contrivances in them. For we have here a large family of animals, in every particular refpect, curioufly contrived and made, for that efpecial pofture, place, food, and office or bufinefs which they obtain in the world. So that if we confider their own particular happinefs and good, or man's ufe and fervice; or if we view them throughout, and confider the parts wherein they agree with man, or thofe efpecially wherein

wherein they differ; we ſhall find all to be ſo far from being things fortuitous, undeſigned, or any way accidental, that every thing is done for the beſt; all wiſely contrived, and incomparably fitted up, and every way worthy of the great Creator. And he that will ſhut his eyes, and not ſee God [m] in theſe his works, even of the poor beaſts of the earth, that will not ſay, as Elihu hath it, Job xxxv. 10, 11. 'Where is God my Maker, 'who teacheth us more than the beaſts of the 'earth, and maketh us wiſer than the fowls of 'the heaven?' Of ſuch an one we may uſe the 'pſalmiſt's expreſſion, Pſalm xlix. 12. that he is 'like the beaſts [n] that periſh.'

[m] ———Deum namque ire per omnes
Terraſque tractuſque maris, cœlumque profundum.
Hinc pecudes, armenta, viros, genus omne ferarum.
Virg. Geor. l. 4.

[n] 'Illos qui nullum omnino Deum eſſe dixerunt, non modo non 'philoſophos, ſed ne homines quidem fuiſſe dixerim; qui mutis 'ſimillimi ex ſolo corpore conſtiterunt, nihil videntes animo.' Lactant. l. vii. c. 9.

BOOK

BOOK VII.

A SURVEY OF BIRDS.

HAVING briefly, as well as I could, difpatched the tribe of quadrupeds; I fhall next take a brief and tranfient view of the feathered tribe.

And here we have another large province to expatiate in, if we fhould defcend to every thing wherein the workmanfhip of the Almighty appears. But I muft contract my furvey as much as may be; and fhall therefore give only fuch hints and touches upon this curious family of animals, as may ferve for famples of the reft of what might be obferved.

CHAP.

CHAP. I.

OF THE MOTION OF BIRDS, AND THE PARTS MINISTERING THERETO.

AS this tribe hath a different motion from that of other animals, and an amphibious way of life; partly in the air, and partly on the land and waters; so is their body accordingly shaped, and all their parts incomparably fitted for that way of life and motion; as will be found by a cursory view of some of the particulars. And the

I. And most visible thing is the shape and make of their body, not thick and clumsy, but incomparably adapted to their flight: sharp before, to pierce and make way through the air, and then by gentle degrees rising to its full bulk. To which we may add,

II. The neat poſition of the feathers throughout the body; not ruffled, or diſcompoſed, or placed ſome this, ſome a contrary way, according to the method of chance; but all artificially placed [o], for facilitating the motion of the body, and its ſecurity at the ſame time, by way of clothing: and for that end, moſt of the feathers tend backward, and are laid over one another in exact and regular method, armed with warm and ſoft down next the body, and more ſtrongly made, and curiouſly cloſed next the air and weather, to fence off the injuries thereof. To which purpoſe, as alſo for the more eaſy and nimble gliding of the body through the air, the proviſion nature hath made, and the inſtinct of theſe animals to preen and dreſs their feathers, is admirable; both in reſpect of their art and curioſity in doing it, and the oil-bag [p], glands, and whole apparatus for that ſervice.

[o] See before, book iv. chap. 12.

[p] Mr. Willoughby ſaith, there are two glands for the ſecretion of the unctuous matter in the oil-bag. And ſo they appear to be in geeſe. But upon examination, I find, that in moſt other birds, ſuch at leaſt as I have inquired into, there is only one gland; in which are divers little cells, ending in two or three larger cells, lying under the nipple of the oil-bag. This nipple is perforated, and being preſſed, or drawn by the bird's bill, or head, emits the liquid oil, as it is in ſome birds, or thicker unctuous greaſe, as it is in others. The whole oil-bag is in its ſtructure ſomewhat conformable to the breaſts of ſuch animals as afford milk.

III. AND

III. And now having ſaid thus much relating to the body's motion, let us ſurvey the grand inſtrument thereof, the wings. Which as they are principal parts, ſo are made with great ſkill, and placed in the moſt commodious point of the body[1], to give it an exact equipoiſe in that ſubtle medium, the air.

And here it is obſervable, with what incomparable curioſity every feather is made; the ſhaft exceeding ſtrong, but hollow below, for ſtrength and lightneſs ſake; and above, not much leſs ſtrong, and filled with a parenchyma or pith, both ſtrong and light too. The vanes as nicely gauged on each ſide as made; broad on one ſide, and narrower on the other; both which incomparably miniſter to the progreſſive motion of the bird,

[1] In all birds that fly much, or that have the moſt occaſion for their wings, it is manifeſt that their wings are placed in the very beſt part, to balance their body in the air, and to give as ſwift a progreſſion, as their wings and body are capable of: for otherwiſe we ſhould perceive them to reel, and fly unſteadily: as we ſee them to do, if we alter their æquipoiſe, by cutting the end of one of the wings, or hanging a weight at any of the extreme parts of the body. But as for ſuch birds as have as much occaſion for ſwimming as flying, and whoſe wings are therefore ſet a little out of the centre of the body's gravity, ſee book iv. chap. 8. and for ſuch as have more occaſion for diving than flying, and whoſe legs are, for that reaſon, ſet more backward, and their wings more forward, ſee chap. 4. of this book.

bird, as also to the union and closeness of the wing[1].

And no less exquisite is the textrine art of the plumage also[2]; which is so curiously wrought, and

[1] The wise Author of nature hath afforded an example of the great nicety in the formation of birds, by the nicety observed in a part no more considerable than the vanes of the flag-feathers of the wing. Among others, these two things are observable: 1. The edges of the exterior or narrow vanes bend downwards, but of the interior wider vanes upwards; by which means they catch, hold, and lie close to one another, when the wing is spread; so that not one feather may miss its full force and impulse upon the air. 2. A yet lesser nicety is observed, and that is, in the very sloping the tips of the flag-feathers: the interior vanes being neatly sloped away to a point, towards the outward part of the wing; and the exterior vanes sloped towards the body, at least in many birds; and in the middle of the wing, the vanes being equal, are but little sloped. So that the wing, whether extended or shut, is as neatly sloped and formed, as if constantly trimmed with a pair of scissors.

[2] Since no exact account, that I know of, hath been given of the mechanism of the vanes, or webs of the feathers, my observation may not be unacceptable. The vane consists not of one continued membrane; because if once broken, it would hardly be reparable; but of many laminæ, which are thin, stiff, and somewhat of the nature of a thin quill. Towards the shaft of the feather, (especially in the flag-feathers of the wing,) those laminæ are broad, &c. of a semicircular form; which serve for strength, and for the closer shutting of the laminæ to one another, when impulses are made upon the air. Towards the outward part of the vane, these laminæ grow slender and taper: on their under side they are thin and smooth, but their upper-outer edge is parted into two hairy edges, each side having a different sort of hairs, laminated or broad at bottom, and slender and bearded above the other half. I have, as well as I could,

and ſo artificially interwoven, that it cannot be viewed without admiration eſpecially when the eye is aſſiſted with glaſſes.

And as curiouſly made, ſo no leſs curiouſly are the feathers placed in the wings, exactly according to their ſeveral lengths and ſtrength: the principals ſet for ſtay and ſtrength, and theſe again well lined, faced, and guarded with the covers and ſecondary feathers, to keep the air from paſſing through, whereby the ſtronger impulſes are made thereupon.

And laſtly, to ſay no more of this part, that deſerves more to be ſaid of it, what an admirable apparatus is there of bones, very ſtrong, but withal light and incomparably wrought! of joints, which open, ſhut, and every way move,

could, repreſented the uppermoſt edge of one of theſe laminæ in Fig. 18. with ſome of the hairs on each ſide, magnified with a microſcope. Theſe bearded briſtles, or hairs, on one ſide the laminæ, have ſtrait beards, as in Fig. 19. thoſe on the other ſide, have hooked beards on one ſide the ſlender part of the briſtle, and ſtrait ones on the other, as in Fig. 20. Both theſe ſorts of briſtles magnified, (only ſcattering, and not cloſe,) are repreſented as they grow upon the upper edge of the lamina S t, in Fig. 18. And in the vane, the hooked beards of one lamina always lie next the ſtrait beards of the next lamina; and by that means look and hold each other; and by a pretty mechaniſm, brace the laminæ cloſe to one another. And if at any time the vane happens to be ruffled and diſcompoſed, it can, by this pretty eaſy mechaniſm, be reduced and repaired. Vide book iv. chap. 12.

according

according to the occaſions either of extending it in flight, or withdrawing the wing again to the body! and of various muſcles; among which the peculiar ſtrength of the pectoral muſcles deſerves eſpecial remark, by reaſon they are much ſtronger [t] in birds than in man, or any other animal, not made for flying!

IV. Next the wings, the tail is in flight conſiderable; greatly aſſiſting in all aſcents and deſcents in the air, as alſo ſerving to ſteady flight [u], by

[t] 'Pectorales muſculi hominis flectentes humeros, parvi et parum 'carnoſi ſunt; non æquant 50am aut 70am partem omnium muſ'culorum hominis. E contra in Avibus, pectorales muſculi vaſtiſ'ſimi ſunt, et æquant, imo excedunt, et magis pendent, quam reli'qui omnes muſculi ejuſdem avis ſimul ſumpti.' Borell. de Mot. 'Animal. vol. 1. prop. 184.

Mr. Willoughby, having made the like obſervation, hath this reflection on it. 'Whence, if it be poſſible for man to fly, it is 'thought by them who have curiouſly weighed and conſidered the 'matter, that he that would attempt ſuch a thing with hopes of ſuc'ceſs, muſt ſo contrive and adapt his wings, that he may make uſe of 'his legs, and not his arms, in managing them:' (becauſe the muſcles 'of the legs are ſtronger, as he obſerves.) Willough. Ornith. l. i. c. 1. ſect. 19.

[u] Mr. Willoughby, Ray, and many others, imagine the principal uſe of the tail to be to ſteer and turn the body in the air as a rudder. But Borelli hath put it beyond all doubt, that this is the leaſt uſe of it, and that it is chiefly to aſſiſt the bird in its aſcents and deſcents in the air, and to obviate the vacillations of the body and wings. For, as for turning to this or that ſide, it is performed by the

by keeping the body upright in that fubtle and yielding medium, by its readily turning and anfwering every acillation of the body.

And now to the parts ferving to flight, let us add the nice and complete manner of its performance; all done according to the ftricteft rules of mechanifm [v]. What rower on the waters, what artift on the land, what acuteft mathematician could give a more agreeable and exact motion to the wings, than thefe untaught flying artifts do to theirs! Serving not only to bear their bodies up in the air, but alfo to waft them along therein, with a fpeedy progreffive motion, as alfo to fteer and turn them this way and that way, up and down, fafter or flower, as their occafions require, or their pleafure leads them.

V. Next to the parts for flight, let us view the feet and legs miniftering to their other motions: both made light, for eafier tranfportation through the air; and the former fpread, fome with mem-

the wings and inclinations of the body and but very little by the help of the tail.

[v] See Borelli, ubi fupra, prop. 182, &c.

branes for swimming [w], some without, for steady going, for perching, for catching and holding of prey [x], or for hanging by the heels, to gather their food [z], or to fix themselves in their place of retreat and safety. And the latter, namely, the legs, all curved for their easy perching, roosting,

[w] It is considerable in all water-fowl, how exactly their legs and feet correspond to that way of life. For either their legs are long, to enable them to wade in the waters: in which case, their legs are bare of feathers a good way above the knees, the more conveniently for this purpose. Their toes also are all broad; and in such as bear the name of mud-suckers, two of the toes are somewhat joined, that they may not easily sink in walking upon boggy places. And as for such as are whole-footed, or whose toes are webbed together, except some few, their legs are generally short, which is the most convenient size for swimming. And it is pretty enough to see how artificially they gather up their toes and feet when they withdraw their legs, or go to take their stroke; and as artificially again extend or open their whole foot, when they press upon, or drive themselves forward in the waters.

[x] Some of the characteristics of rapacious birds, are, 'to have 'hooked, strong, and sharp-pointed beaks and talons, fitted for 'rapine, and tearing of flesh; and strong and brawny thighs, for 'striking down their prey.' Willoughby Ornith. l. ii. c. 1. Raii. Synops. Av. Method. p. 1.

[z] Such birds as climb, particularly those of the wood-pecker-kind, have for this purpose, (as Mr. Willoughby observes, l. 2. c. 4.) 1. Strong and musculous thighs. 2. Short legs and very strong. 3. Toes standing two forwards and two backwards. Their toes also are close jointed together, that they may more strongly and firmly lay hold on the tree they climb upon. 4. All of them have a hard stiff tail, bending also downwards, on which they lean, and so bear up themselves in climbing.

and

and reſt, as alſo to help them upon their wings in taking their flight, and to be therein commodiouſly tucked up to the body, ſo as not to obſtruct their flight. In ſome long, for wading and ſearching the waters; in ſome of a moderate length, anſwerable to their vulgar occaſions; and in others as remarkably ſhort, to anſwer their eſpecial occaſions and manner of life [a]. To all theſe let us add the placing theſe laſt mentioned parts in the body. In all ſomewhat out of the center of the body's gravity [b], but in ſuch as

[a] Swifts and ſwallows have remarkably ſhort legs, eſpecially the former, and their toes graſp any thing very ſtrongly. All which is uſeful to them in building their neſts, and other ſuch occaſions as neceſſitate them to hang frequently by their heels. But there is far greater uſe of this ſtructure of their legs and feet, if the reports be true of their hanging by the heels in great cluſters, after the manner of bees, in mines and grottos, and on the rocks by the ſea, all the winter. Of which latter, I remember the late learned Dr. Fry told this ſtory at the univerſity, and confirmed it to me ſince, viz. that an ancient fiſherman, accounted an honeſt man, being near ſome rocks on the coaſt of Cornwall, ſaw at a very low ebb, a black liſt of ſomething adhering to the rock, which when he came to examine, he found it was a great number of ſwallows, and, if I miſremember not, of ſwifts alſo, hanging by the feet to one another, as bees do; which were covered commonly by the ſea waters, but revived in his warm hand, and by the fire. All this the fiſherman himſelf aſſured the doctor of. Of this, ſee more, chap. 3. of this book.

[b] In birds that frequent not the waters, the wings are in the centre of gravity, when the bird lies along, as in flying; but when it ſtands or walks, the erection of the body throws the centre of gravity upon the thighs and feet.

ſwim, more than in others, for the better rowing their bodies through the waters, or to help them in their diving too [c].

[c] See chap. 4.

CHAP.

CHAP. II.

OF THE HEAD, STOMACH, AND OTHER PARTS OF BIRDS.

THUS having difpatched the parts principally concerned in the motion of the feathered tribe, let us proceed to fome other parts not yet animadverted upon. And we will begin with the head, concerning which I have already taken notice of its fhape for making way through the air; of the make of the bill, for gathering food, and other ufes; the commodious fituation of the eye; and I might add that of the ear too, which would be in the way, and obftruct flight, if it was like that of moft other animals: alfo I might fay a great deal of the conformation of the brain [d], and of the parts therein wanting, and

[d] 'Cerebra hominum et quadrupedum in plerifque fimilia ex-'iftunt.—Capitibus volucrum et pifcium contenta, ab utrifque pri-oribus

and of others added, like to what is obſervable in fiſhes; whoſe poſture in the waters reſembles that of birds in the air [e], and both very different from man and beaſts; and laſtly, to hint at no more, I might ſurvey the peculiar ſtructure of the larynx [f], the tongue [g], the inner ear [h], and many

'oribus longe diverſa, tamen inter ſe, quoad præcipuas ἐγκεφάλου 'partes, ſymbola reperiuntur.' The particulars wherein the brains of birds and fiſhes agree with one another, and wherein they differ from the brain of man and beaſt, ſee in the ſame juſtly famous author, Willis. Cereb. Anat. c. 5.

[e] 'Circa bifurcationem aſperæ arteriæ, elegans artificis libere 'agentis indicium detegitur ex avium comparatione cum quadruped- 'ibus: cum vocis gratia in diverſis avibus diverſam muſculorum 'fabricam bifurcationi aſperæ arteriæ dederit, quorum nullum 'veſtigium extat in homine et quadrupedibus mihi viſis, ubi omnes 'vocis muſculos capiti arteriæ junxit. In aquila, etc. ſupra bifur- 'cationem,' etc. Steno in Blaſ. Anat. Animal. p. 2. c. 4.

[f] The aſpera arteria is very remarkable in the ſwan, which is thus deſcribed by T. Bartholin, viz. 'Aſpera arteria admirandæ ſatis 'ſtructura. Nam pro colli longitudine deorſum œſophagi comes 'protenditur donec ad ſternum perveniat, in cujus capſulam ſe in- 'curvo flexu inſinuat et recondit, velut in tuto loco et theca, mox- 'que ad fundum ejuſdem cavitatis delata ſurſum reflectitur, egredi- 'turque anguſtias ſterni, et claviculis mediis conſcenſis, quibus ut 'fulcro nititur, ad thoracem ſe flectit——Miranda hercle modis 'omnibus conſtitutio et reſpirationi inſervit et voci. Nam cum in 'ſtagnorum fundo edulia pro victu quærat, longiſſimo indiguit 'collo, ne longa mora ſuffocationis incurreret periculum. Et certe 'dum dimidiam fere horam toto capite et collo pronis vado immer- 'gitur, pedibus in altum elatis cœloque obverſis, ex ea arteriæ 'quæ

many matters befides; but for a fample, I fhall only infift upon the wonderful provifion in the bill for the judging of the food, and that is by peculiar

'quæ pectoris dictæ vaginæ reclufa eft portione, tanquam ex condo 'promo fpiritum haurit.' Blaf. ib. c. 10.

[g] The ftructure of the tongue of the wood-pecker is very fingular and remarkable, whether we look at its great length, its bones and mufcles, its encompaffing part of the neck and head, the better to exert itfelf in length, and again, to retract it into its cell; and laftly, whether we look at its fharp, horny, bearded point, and the glewy matter at the end of it, the better to ftab, to flick unto, and draw out little maggots out of wood. 'Utilis enim picis (faith 'Coiter) ad vermiculos, formicas, aliaque infecta venanda talis 'lingua foret. Siquidem picus, innata fua fagacitate cum depre'hendit alibi in arboribus, vel carie, vel alia de caufa cavatis, ver'mes infectaque delitefcere, ad illas volitat, fefeque digitis, ungulif'que pofterioribus robuftiffimis, et caudæ pennis rigidiffimis fuf'tentat, donec valido ac peracuto roftro arborem pertundat: arbore 'pertufa, foramini roftrum immittit, ac quo animalcula ftridore 'excitet percellatque, magnam in arboris cavo emittit vocem, infecta 'vociferatione hac concitata huc illucque repunt; picus vero linguam 'fuam exerit, atque aculeis hamifque animalia infigit, infixa attrahit 'et devorat.' Vide Blafii, ubi fupra, p. 2. c. 24.

[h] I have before, in book iv. chap. 3. taken notice of what others have obferved concerning the inner ear of birds, referving my own obfervations for this place: which I hope may be acceptable, not only for being fome of them new, but alfo fhewing the mechanifm of hearing ing eneral.

In this organ of birds, I fhall take notice only of three parts, the membranes and cartilages; the columella; and the conclave, the drum, as fome call it, or membrana tympani, as others, confifts of two membranes, the outer, which covers the whole meatus,

 bafon,

peculiar nerves lodged therein for that purpose; small and less numerous in such as have the assistance of another sense, the eye; but large, more

bason, or drum, as some call it, and the inner membrane. To support, distend, and relax the outermost, there is one single cartilage, reaching from the side of the meatus, to near the middle of the membrane. On the top of the columella is another cartilage, consisting of three branches, a, b, c, in Fig 23. The longest middle branch, a, is joined to the top of the single upper cartilage before spoken of, and assists it to bear up the upper outer membrane: the two branches, b, e, are joined to the os petrosum, at some distance from the outer membrane: upon this inner cartilage, is the inner membrane fixed, the two outer sides of which, a, b, and a, e, are joined to the outer membrane, and make a kind of a three square bag. The design of the two branches or legs of the cartilage, b, c, are, I conceive, to keep the cartilage and columella from wavering side ways, and to hinder them from flying too much back: there is a very fine slender ligament extended from the opposite side, quite across the meatus or bason, to the bottom of the cartilage, near its joining to the columella. Thus much for the membrana tympani, and their cartilages.

The next part is the columella, as Schelhammer calls it. This is a very fine' thin, light, bony tube; the bottom of which spreads about, and gives it the resemblance of a wooden pot lid, such as I have seen in country-houses. It exactly shuts into, and covers a foramen of the conclave, to which it is braced all round, with a fine subtle membrane, composed of the tender auditory nerve. This bottom or base of the columella, I call the operculum.

The last part, which some call the labyrinth and cochlea, consisting of branches more like the canales semicirculares in man, than the cochlea, I call the conclave auditus. It is, as in most other animals, made of hard context bone. In most of the birds I have opened, there are circular canals, some larger, some lesser, crossing one more numerous, and thickly branched about, to the very end of the beak, in ſuch as hunt for their

one another at right angles, which open into the conclave. But in the gooſe it is otherwiſe, there being cochleous canals, but not like thoſe of other birds. In the conclave, at the ſide oppoſite to the operculum, the tender part of the auditory nerve enters, and lineth all thoſe inner retired parts, viz. the conclave and canals.

As to the paſſages, columnæ, and other parts obſervable in the ear of birds, I ſhall paſs them by, it being ſufficient to my purpoſe, to have deſcribed the parts principally concerned in the act of hearing. And as the ear is in birds the moſt ſimple and incomplex of any animal's ear; ſo we may from it make an eaſy and rational judgment, how hearing is performed, viz. ſound being a tremor or undulation in the air, cauſed by the colliſion of bodies, doth, as it moves along, ſtrike upon the drum, or membrana tympani, of the ear: which motion, whether ſtrong or languid, ſhrill or ſoft, tuneful or not, is at the ſame inſtant impreſſed upon the cartilages, columella, and operculum, and ſo communicated to the auditory nerve in the conclave.

And now if we compare the organ and act of hearing with thoſe of ſight, we ſhall find that the conclave is to hearing, as the retina is to ſight; that ſonorous bodies make their impreſſions thereby on the brain, as viſible objects do by the retina. Alſo, that as there is an apparatus in the eye, by the opening and ſhutting of the pupil, to make it correſpond to all the degrees of light, ſo there is in the ear, to make it conformable to all the degrees of ſound, a noble train of little bones and muſcles in man, &c. to ſtrain and relax the membrane, and at the ſame time to open and ſhut the baſis of the ſtapes (the ſame as what I call the operculum in birds:) but in birds there is a more ſimple but ſufficient apparatus for this purpoſe, tender cartilages, inſtead of bones and joints, to correſpond to the various impreſſions of ſounds, and to open and ſhut the operculum. Beſides which, I ſuſpect the ligament I mentioned, is only the tendon of a muſcle, reaching to the inner membrana tympani, and join-their food out of ſight in the waters, in mud, or under ground [i].

AND now from the head and mouth, paſs we to its near ally, the ſtomach, another no leſs notable than uſeful part; whether we conſider the elegancy of its fibres and muſcles, or its multiplicity; one to ſoften and macerate, another to digeſt; or its variety, ſuited to various foods, ſome membranous, agreeable to the frugivorous,

joined thereto, as I find by a ſtricter ſcrutiny, and not to the cartilage, as I imagined. By this muſcle, the inner membrane, and by means of that the outer alſo, can be diſtended or relaxed, as it is in man, by the malleus and its muſcle, &c.

[i] ' Flat-billed birds, that grope for their meat, have three pair of ' nerves, that come into their bills, whereby they have that accuracy to diſtinguiſh what is proper for food, and what to be rejected by their taſte, when they do not ſee it. This was moſt evident in a ducks bill and head; ducks having larger nerves that come into their bills than geeſe, or any other bird that I have ſeen; ' and therefore quaffer and grope out their meat the moſt. But ' then I diſcovered none of theſe nerves in round-billed birds. But ' ſince, in my anatomies in the country, in a rook, I firſt obſerved ' two nerves that came down betwixt the eyes into the upper bill, ' but conſiderably ſmaller than any of the three pair of nerves in ' the bills of ducks, but larger than th nerves in any other round-billed birds. And it is remarkable that theſe birds, more than ' any round billed birds, ſeem to grope for their meat in cow-dung,' &c. Mr. J. Clayton, in Philoſo. Tranſ. No. 206.

' I obſerved three pair of nerves in all the broad-billed birds that ' I could meet with, and in all ſuch as feel for their food out of ' ſight, as ſnipes, woodcocks, curlews, geeſe, ducks, teals, widgeons, ' &c. Theſe nerves are very large, equalling almoſt the optic ' nerve or carnivorous kind; ſome muſculous and ſtrong[k], ſuited to the comminution, and grinding of corn and grain, and ſo to ſupply the defect of teeth.

And now to this ſpecimen of the parts, I might add many other things, no leſs curiouſly contrived, made, and ſuited to the occaſions of theſe volatiles; as particularly the ſtructure and lodgement of the lungs[l]; the configuration of the breaſt,

'nerve in thickneſs.——Two are diſtributed nigh the end of the 'upper bill, and are there very much expanded, paſſing through the 'bone into the membrane, lining the roof of the mouth.' Dr. A. Moulen, ibid. No. 199. Or both in Mr. Lowthorp's Abridg. vol. II. p. 861, 862.

[k] The gizzard is not only made very ſtrong, eſpecially in the granivorous; but hath alſo a faculty of grinding what is therein: for which purpoſe, the bird ſwalloweth rough ſtones down, which when grown ſmooth, are rejected and caſt out of the ſtomach as uſeleſs. This grinding may be heard in falcons, eagles, &c. by laying the ear cloſe to them, when their ſtomachs are empty, as the famous Dr. Harvey ſaith, De Gener. Exer 7.

As to the ſtrength of the gizzard, and the uſe of ſtones to the digeſtion of fowls, divers curious experiments may be met with, tried by ſigneur Redi, with glaſs bubbles, ſolid glaſs, diamonds, and other hard bodies. See his Exp. Nat.

[l] It is no leſs remarkable in birds, that their lungs adhere to the thorax, and have but little play, than that in other animals they are looſe, and play much, which is a good proviſion for their ſteady flight. Alſo they want the diaphragm, and inſtead thereof have divers

breaſt, and its bone, made like a keel, for commodious paſſage through the air, to bear the large and ſtrong muſcles, which move the wings, and to counterpoiſe the body, and ſupport and reſt it upon at rooſt. The neck alſo might deſerve our notice, always either exactly proportioned to the length of the legs, or elſe longer, to hunt out food, to ſearch in the waters [m]; as alſo to counterpoiſe the body in flight [n]. And laſtly, I might

divers large bladders made of thin tranſparent membranes, with pretty large holes out of one into the other. Theſe membranes ſeem to me to ſerve for ligaments, or braces to the viſcera, as well as to contain air. Towards the upper part, each lobe of the lungs is perforated in two places, with large perforations; whereof one is towards the outer, the other towards the inner part of the lobe. Through theſe perforations, the air hath a paſſage into the belly as in book i. chap. 1. that is, into the forementioned bladders; ſo that by blowing into the aſpera arteria, the lungs will be a little raiſed, and the whole belly blown up, ſo as to be very turgid. Which doubtleſs is a means to make their bodies more or leſs buoyant, according as they take in more or leſs air to facilitate thereby their aſcents and deſcents; like as it is in the air bladders of fiſhes, in the laſt cited place.

[m] 'Such birds as havs long legs, have alſo a long neck; for that 'otherwiſe they could not commodiouſly gather up their food, 'either on land, or in the water. But on the other ſide, thoſe 'which have long necks, have not always long legs, as in ſwans— 'whoſe necks ſerve them to reach to the bottom of rivers,' &c. Willoughby's Ornithol. l. 1. ſect 7.

[n] We have ſufficient inſtances of this in geeſe, ducks, &c. whoſe wings (their bodies being made for the convenience of ſwimming.) are placed out of the centre of gravity, nearer the head. But

I might here take notice of the defect of the diaphragm, ſo neceſſary in other animals to reſpiration; and alſo of divers other parts redundant, defective, or varying from other animals. But it would be tedious to inſiſt upon all; and therefore to the examples already given, I would rather recommend a nice inſpection ° of thoſe curious works of God, which would be manifeſt demonſtrations of the admirable contrivance and oeconomy of the bodies of thoſe creatures.

FROM the fabric therefore of their bodies, I ſhall paſs to a glance of one or two things, relating to their ſtate; and ſo conclude this genus of the animal world.

But the extending the neck and head in flight, cauſeth a due æquipoiſe and libration of the body upon the wings; which is another excellent uſe of the long necks of theſe birds, beſides that of reaching and ſearching in the waters for their food.

But in the heron, whoſe head and long neck, although tucked up in flight, over-balance the hinder part of the body; the long legs are extended in flight, to counterpoſe the body; as well as to ſupply what is wanting in the tail, from the ſhortneſs of it.

° Steno thus concludes his myology of the eagle, 'Imperfecta 'hæc muſculorum deſcriptio, non minus arida eſt legentibus, quam 'inſpectantibus fuerit jucunda eorundem præparatio. Elegantiſſima 'enim mechanices artificia, creberrime in illis obvia, verbis non 'niſi obſcure exprimuntur, carnium autem ductu, tendinum colore, 'inſertionum proportione, et trochlearum diſtributione oculis ex-'poſita omnem ſuperant admirationem.' Steno in Blaſ. Anat. Animal. p. 2. c. 4.

CHAP.

CHAP. III.

OF THE MIGRATION OF BIRDS.

CONCERNING the ſtate of this tribe of animals, the firſt thing I ſhall ſpeak of, by reaſon God himſelf inſtanceth it, ſhall be their migration, mentioned Jer. viii. 7. 'Yea, the 'ſtork in the heaven knoweth her appointed 'times, and the turtle, and the crane, and the 'ſwallow obſerve the time of their coming; but 'my people,' &c.

IN which act of migration, there are two things to me exceedingly notable. One is what the text ſpeaks of, their knowing their proper times for their paſſage, when to come[p], when

[p] 'Curioſa res eſt, ſcire, quam exacte hoc genus avium [gruum] 'quotannis obſervet tempora ſui reditus ad nos. Anno 1667, 'primæ grues comparuerunt in campeſtribus Piſæ 20 Feb. &c. F. Redi Exp. Nat. p. 100. ubi plura.

to

to go; as alſo that ſome ſhould come, when others go; and ſome others go, when theſe come. There is no doubt but the temperature of the air, as to heat and cold, and their natural propenſity to breed their young, may be great incentives to thoſe creatures to change their habitation: but yet it is a very odd inſtinct, that they ſhould at all ſhift their habitation; that ſome certain place is not to be found in all the terraqueous globe, affording them convenient food and habitation all the year, either in the colder climes, for ſuch as delight in the colder regions; or the hotter, for ſuch birds of paſſage as fly to us in ſummer.

Also it is ſomewhat ſtrange, that thoſe untaught, unthinking creatures ſhould ſo exactly know the beſt and only proper ſeaſons to go and come. This gives us good reaſon to interpret the מיעריה *appointed times* [q] in the text, to be ſuch times as the Creator hath appointed thoſe animals, and hath

[q] From יעד 'indixit, conſtituit, ſcil. locum, vel tempus, ubi 'vel quando aliquid fieri debet.' Buxt. in verb.

'De voluntate ſua certiorem reddidit.' C. Kircher Concordant. Pars 1. Col. 1846. מועד 'Generaliter pro re aliqua certa, atteſtata, et definita accipitur. 1. Pro tempore certo et conſtituto. '2. Deinde pro feſto ſeu ſolennitate, quæ certo et ſtato tempore 'celebratur. 3. Pro loco certo conſtituto.' Id. ibid. Col. 1847.

accord-

accordingly, for this end, imprinted upon their natures ſuch an inſtinct, as exciteth and moveth them thus, at proper times, to fly from a place that would obſtruct their generation, or not afford convenient food for them, and their young, and betake themſelves to another place, affording all that is wanting for food or incubation.

AND this leads me to another thing remarkable in this act of migration; and that is, that thoſe unthinking creatures ſhould know what way to ſteer their courſe [r], and whither to go. What but the great Creator's inſtinct ſhould ever move a poor fooliſh bird, to venture over vaſt tracks of land, but eſpecially over large ſeas? If it ſhould be ſaid, that by their high aſcent up into the air, they can ſee croſs the ſeas; yet what ſhould teach or perſuade them, that that land is more proper for their purpoſe than this? That Britain,

[r] 'Quis non cum admiratione videat ordinem et politiam pere-'grinantium avium, in itinere, turmatim volantium, per longos 'terrarum et maris tractus abſque acu marina——Quis eas certum 'iter in aeris mutabili regione docuit? Quis præteritæ ſigna, et 'futuræ viæ indicia? Quis eas ducit, nutrit, et vitæ neceſſaria 'miniſtrat? Quis inſulas et hoſpitia illa, in quibus victum reperiat, 'indicavit; modumque ejuſmodi loca in peregrinationibus ſuis in-'veniendi? Hæc ſane ſuperant hominum captum et induſtriam, qui 'non niſi longis experientiis, multis itinerariis, chartis geographicis, '——et acus magneticæ beneficio,——ejuſmodi marium et terra-'rum tractus conficere tentant, et audent.' Lud. de Beaufort. Coſm. Divina, ſect. 5. c. 1.

for

for inſtance, ſhould afford them better accommodations than Egypt [s], than the Canaries, than Spain, or any of thoſe many intermediate places over which ſome of them probably fly.

[s] I inſtance particularly in Egypt, becauſe Mr. Willoughby thinks ſwallows fly thither, and into Ethiopia, &c. and that they do not lurk in holes, or under water, as Olaus Magnus reports. Vide Ornith. l. 2. c. 3. But Etmuller puts the matter out of doubt, who ſaith, 'Memini me plures, quam quas medimnus ceperit, hirundines arcte coacervatas inter piſcinæ cannas, ſub glacie prorſus ad ſenſum exanimes, pulſantes tamen, reperiiſſe.' Etmul. Diſſert. 2. c. 10. ſect. 5. This, as it is like what Ol. Magnus ſaith, ſo it is a a confirmation of it. The archbiſhop's account is, 'In ſeptentrionalibus aquis ſæpius caſu piſcatoris extrahuntur hirundines, in modum conglomeratæ maſſæ, quæ ore ad os, et ala ad alam, et pede ad pedem poſt principium autumni ſeſe inter cannas deſcenſuræ colligarunt.—Maſſa autem illa per imperitos adoleſcentes—extracta, atque in æſtuaria portata, caloris acceſſu hirundines reſolutæ, volare quidem incipiunt, ſed exiguo tempore durant.' Ol. Mag. Hiſt. l. 19. c. 20.

Since my penning this note, we had, at a meeting of the Royal Society, Feb. 12, 1712-13, a farther confirmation of ſwallows retiring under water in winter, from Dr. Colas, a perſon very curious in theſe matters; who ſpeaking of their way of fiſhing in the northern parts, by breaking holes, and drawing their nets under the ice, ſaith, that he ſaw ſixteen ſwallows ſo drawn out of the lake of Samrodt, and about thirty out of the King's great pond in Roſineilen; and that at Schlebittin, near an houſe of the Earl of Dohna, he ſaw two ſwallows juſt come out of the waters, that could ſcarce ſtand, being very wet and weak, with their wings hanging on the ground; and that he hath obſerved the ſwallows to be often weak for ſome days after their appearance.

 And

And laſtly, to all this, let us briefly add the accommodations theſe birds of paſſage have to enable them to take ſuch long flights, viz. the length of their wings, or their more than ordinary ſtrength for flight [t].

[t] As ſwallows are well accommodated for long flights, by their long wings, ſo are quails by the ſtrength of their pectoral muſcles, by the breadth of their wings, &c. For quails have but ſhort wings for the weight of their body; and yet they fly from us into warmer parts againſt winter, and to us in the ſpring, croſſing our ſeas. So divers travellers tell us, they croſs the Mediterranean twice a year, flying from Europe to Africa, and back again: thus Bellonius, in Mr. Willouhgby, ſaith, ' When he ſailed from Rhodes ' to Alexandria of Egypt, many quails, flying from the north to- ' wards the ſouth, were taken in our ſhip; whence I am verily per- ' ſuaded, that they ſhift places: for formerly alſo, when I ſailed out ' of the iſle of Zant to Morea, or Negropont, in the ſpring time, I ' had obſerved quails flying the contrary way, from ſouth to north, ' that they might abide there all ſummer. At which time alſo, ' there were a great many taken in our ſhip.' Ornith. p. 170.

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CHAP. IV.

OF THE INCUBATION OF BIRDS.

ANOTHER thing relating to the ſtate of this tribe of animals, is their incubation.

AND firſt, the egg itſelf deſerves our notice. Its parts within, and its cruſty coat without, are admirably well fitted for the buſineſs of incubation. That there ſhould be one part provided for the formation of the body [u], before its exit into

[u] The chicken is formed out of, and nouriſhed by the white alone, ‘ till it be grown great. The yolk ſerves for the chicken's nouriſhment, after it is well grown, and partly alſo after it is hatched. ‘ For a good part of the yolk remains after excluſion, being received ‘ into the chicken's belly; and being reſerved, as in a ſtore houſe, ‘ is by the [appendicula, or ductus inteſtinalis,] as by a funnel, conveyed into the guts, and ſerves inſtead of milk,’ &c. Willoughby's Ornith. l. 1. c. 3. ‘ Ipſum animal ex albo liquore ovi corporatur. Cibus ejus in luteo eſt.’ Plin. l. 10. c. 53.

into the world, and another for its nouriſhment, after it is come into the world, till the bird is able to ſhift for, and help itſelf; and that theſe parts ſhould be ſo accurately braced, and kept in due place [v], is certainly a deſigned, as well as curious piece of workmanſhip.

Ariſtotle ſaith 'The long ſharp eggs bring females; the round 'ones, with a larger compaſs at the ſharper end, males.' Hiſt. An. l. 6. c. 2. After which he tells of a ſot at Syracuſe, that ſat drinking ſo long, till eggs were hatched; as alſo of the cuſtom of Egypt, of hatching eggs in dunghills.

[v] As the ſhell and ſkin keep the yolk and two whites together; ſo each of the parts (the yolk and inner white at leaſt) are ſeparated by membranes, involving them. At each end of the egg is a treddle, ſo called, becauſe it was formerly thought to be the ſperm of the cock. 'But the uſe of theſe, (ſaith Dr. Harvey, in Wil-'loug. Ornith. c. 3.) is to be as it were, the poles of this microcoſm, 'and the connections of all the membranes twiſted and knit together, 'by which the liquors are not only conſerved, each in its place, 'but do alſo retain their due poſition one to another.' This although in a great meaſure true, yet doth not come up to what I have myſelf obſerved; for I find, that theſe chalzae, or treddles, ſerve not barely to keep the liquors in their place, and poſition to one another; but alſo to keep one and the ſame part of the yolk uppermoſt, let the egg be turned nearly which way it will; which is done by this mechaniſm: the chalzae are ſpecifically lighter than the whites, in which they ſwim; and being braced to the membrane of the yolk, not exactly in the axis of the yolk, but ſomewhat out of it, cauſeth one ſide of the yolk to be heavier than the other; ſo that the yolk being by the chalzae made buoyant, and kept ſwimming in the midſt of two whites, is by its own heavy ſide kept with the ſame ſide always uppermoſt; which uppermoſt ſide, I have ſome reaſon to think, is that on which the cicatricula lies; that being commonly uppermoſt in the ſhell, eſpecially in ſome ſpecies of eggs more I think, than others.

AND

And then as to the act itfelf of incubation, what a prodigious inftinct is it, in all or almoft all the feveral fpecies of birds, that they, and only they, of all creatures, fhould betake themfelves to this very way of generation! How fhould they be aware that their eggs contain their young, and that their production is in their power[w]! What fhould move them to betake themfelves to their nefts, and there with delight and patience to abide the due number of days! And when their young are gotten into the world, I have already fhewn how admirable their art, their care, and Στοργὴ is in bringing them up until, and only until, they are able to fhift for themfelves.

And laftly, when almoft the whole tribe of birds do thus, by incubation, produce their young, it is a wonderful deviation, that fome few families only fhould do it in a more novercal way[x], without any care or trouble at all, only

[w] All birds lay a certain number of eggs, or nearly that number, and then betake themfelves to their incubation; but if their eggs be withdrawn, they will lay more. Of which, fee Mr. Ray's Wifdom of God, p. 137.

[x] The tahon is a bird no bigger than a chicken, but is faid to lay an egg larger than a goofe's egg, and bigger than the bird itfelf. Thefe they lay a yard deep in the fand, where they are hatched by the warmth of the fun, after which they creep out, and get to

only by laying their eggs in the ſand, expoſed to the heat and incubation of the ſun. Of this the Holy Scripture itſelf gives us an inſtance in the oſtrich: of which we have an hint, Lam. iv. 3. 'The daughter of my people is become 'cruel, like the oſtriches in the wilderneſs.' This is more plainly expreſſed in Job. xxxix. 14, 15, 16, 17. '(The oſtrich leaveth her eggs in 'the earth, and warmeth them in the duſt, and 'forgetteth that the foot may cruſh them, or 'that the wild beaſt may break them. She is 'hardened againſt her young ones, as though 'they were not hers; her labour is in vain, 'without fear. Becauſe God hath deprived her 'of wiſdom, neither hath he imparted unto her 'underſtanding.' In which words I ſhall take notice of three things: 1. Of this anomalous way of generation. It is not very ſtrange, that no other incubation but that of the ſun, ſhould

ſea for proviſions, Navarette's account of China, in Collect. of Voyages, vol. 1. This account is, in all probability, borrowed from Nieremberg, or Hernandez, (that copied from him,) who calls this bird by the name of Daie, and its eggs tapun, not the bird itſelf, as Navarette doth. But my friend, Mr. Ray, ſaith of it, 'Hiſtoria iſthæc proculdubio fabuloſa et falſa eſt. Quamvis enim aves nonnullæ maxima ova pariwnt, ut v. g. Alkæ, Lomwiæ, 'Arates, Arcticæ, &c. hujuſmodi tamen unum duntaxat, non plura' 'ova ponunt antequam incubent: nec ullam in rerum natura avem 'dari exiſtimo cujus ova albumine careant. Cum albumen præcipua 'ovi pars ſit, quodque primum fœtui alimentum ſubminiſtrat.' Raii. Synop. Av. Meth. p. 155.

produce

produce their young; but it is very odd and wonderful that any one ſpecies ſhould vary at all from the reſt of the tribe. But above all, 2. The ſingle care of the Creator, in this caſe, is very remarkable, in ſupplying ſome other way the want of the parent-animal's care and στοργὴ[y], ſo that the young ſhould, notwithſtanding, be bred up in thoſe large and barren deſarts of Arabia and Africa, and ſuch like places where thoſe birds dwell, the moſt unlikely and unfitting, in all human opinion, to afford ſuſtenance to young helpleſs creatures; but the fitteſt therefore, to give demonſtrations of the wiſdom, care, and eſpecial providence of the infinite Creator and Conſervator of the world. 3. The laſt thing I ſhall remark is, that the inſtincts of irrational animals, at leaſt of this ſpecified in the text, are attributed to God. For the reaſon the text gives why the ' oſtrich is hardened againſt her

[y] ' The eggs of the oſtrich being buried in the ſand, are cheriſhed ' only by the heat of the ſun, till the young be excluded: for the ' writers of natural hiſtory do generally agree, that the old birds, ' after they have laid and covered their eggs in the ſand, forſake ' them, and take no more care of them.' Willough. Ornith. l. 2 c. 8. ſect. 1.

But there is another oſtrich [of America] which Acaret tells us of, that takes more care of her young, by carrying four of her eggs, a little before ſhe hatcheth, to four parts of her neſt, there to breed worms for food for her young. Acaret's Diſc. in Phil. Tranſ. N° 89.

'young ones, as though they were not hers,' is, 'becaufe God hath deprived her of wifdom, 'and not imparted underftanding unto her; i. e. he hath denied her that wifdom, he hath not imparted that underftanding, that στοργή, that natural inftinct to provide for and nurfe up her young, that moft other creatures of the fame, and other tribes, are endowed with.

THUS I have difpatched what I intended to infift upon concerning the ftate of this fet of animals; of which, as alfo of their admirable inftincts, a great deal more might deferve our efpecial obfervation; particularly the admirable curiofity, art, and variety of nidification [z], ufed among the various fpecies of birds; the great fagacity, and many artifices ufed by them in the inveftigation and capture of their prey [a], the due proportion of the more and lefs ufeful, the fcarcity of the voracious and pernicious, and the plenty of the manfuete and ufeful [b]. Alfo the variety of their motions and flight might deferve confideration, the fwiftnefs of fuch whofe food is to be fought in far diftant places, and different

[z] See book iv. chap. 13.

[a] See book iv. chap. 11. and 14.

[b] See book iv. the beginning of chap. 10.

feafons;

feaſons [c]; the flower motion, and ſhort flights, of others more domeſtic; and even the aukwardneſs of ſome others to flight, whoſe food is near at hand, and to be gotten without any great occaſion of flight [d]. Theſe, and divers other ſuch like things as theſe, I ſay, I might have ſpoken more largely unto; but I ſhall paſs them by with only a bare mention, having already taken notice of them in the company of other matters of the like nature, and manifeſted them to be acts of excellent deſign, wiſdom, and providence in the great Creator.

[c] See book iv. chap. 8.

[d] The colymbi, or duckers, having their food near at hand in the waters, are remarkably made for diving therein. Their heads are ſmall, bills ſharp-pointed, wings ſmall, legs flat and broad, and placed backward, and nearer the tail than in other birds; and laſtly, their feet, ſome are whole-footed, ſome cloven footed, but withal fin-toed. Vide Willough. Ornith. l. 3. ſect. 5.

CHAP.

CHAP. V.

THE CONCLUSION.

AND now if we reflect upon the whole matter, we ſhall here find another large tribe of the creation, abundantly ſetting forth the wiſdom and glory of the great Creator. We praiſe the ingenuity and invention of men, for the contrivance of various pneumatic engines; we think them witty, even for their unſucceſsful attempts to ſwim in, and ſail through that ſubtle element the air; and the curious mechaniſm of that artiſt is had in remembrance, and praiſed to this day, who made a dove, or an eagle [e] to fly but a ſhort ſpace. And is not therefore all imaginable honour and praiſe due to that infinite Artiſt, that hath ſo admirably contrived and made all the noble variety of birds; that hath, with ſuch incomparable curioſity and art, formed their bo-

[e] Vide book v. chap. 1.

dies from head to tail, without and within, that not so much as any muscle, or bone, no, not even a feather[f] is unartificially made, misplaced, redundant, or defective, in all the several families of this large tribe? But every thing is so incomparably performed, so nicely fitted up for flight, as to surpass even the imitation of the most ingenious artificer among mortal rational beings.

[f] 'Deus non solum angelum, et hominem, sed nec exigui et con-
'temtibilis animantis viscera, nec avis pennulam, nec herbæ flosculum, nec arboris folium, sine suarum partium convenientia dereliquit.' Augustin. de Civ. Dei. l. 5. c. 11.

BOOK

BOOK VIII.

OF INSECTS AND REPTILES.

CHAP. I.

OF INSECTS IN GENERAL.

HAVING difpatched that part of the animal world, which ufed to be accounted the more perfect, thofe animals ftiled lefs perfect, or imperfect, will next deferve a place in our furvey, becaufe when ftrictly inquired into, we fhall find them to be fo far from deferving to be accounted mean and defpicable parts of the creation, owing their original and production to putrefactions, &c. as fomehave thought, that we fhall find

find them, I ſay, noble, and moſt admirable works of God. For as the famous natural hiſtorian, Pliny[g], prefaceth his Treatiſe of Inſects, to prevent the reproach of condeſcending, as might be thought, to ſo mean a ſubject; 'In great bodies, ſaith he, 'nature had a large and eaſy ſhop to work upon 'obſequious matter; whereas, in theſe ſo ſmall, 'and as it were no bodies, what footſteps of rea- 'ſon, what power what great perfection is there!' Of this having given an inſtance or two of the exquiſite ſenſes, and curious make of ſome inſects[h], he then goes on, 'We admire, ſaith he, the tur- 'rigerous ſhoulders of elephants, the lofty 'necks and creſts of others: but, ſaith he, the 'nature of things is never more complete than

[g] 'In magnis ſiquidem corporibus,' &c. Plin. Nat. Hiſt. l. 11. c. 2.

[h] 'Ubi tot ſenſus collocavit in culice? Et ſunt alia dictu minora. 'Sed ubi viſum in eo prætendit Ubi guſtatum applicavit? Ubi 'odoratum inſeruit? Ubi vero truculentam illam et portione maxi- 'mam vocem ingeneravit? Qua ſubtilitate pennas adnexuit? 'prælongavit pedum crura? Diſpoſuit jejunam caveam, uti alvum? 'Avidam ſanguinis, et potiſſimum humani, ſitim, accendit? Telum 'vero perfodiendo tergori, quo ſpiculavit ingenio? Atque ut in 'capaci, cum cerni non poſſit exilitas, ita reciproca geminavit arte, 'ut fodiendo acuminatum pariter ſorbendoque fiſtuloſum eſſet. Quos 'teredini ad perforanda robora cum ſono teſte dentes affixit? Po- 'tiſſimumque e ligno cibatum fecit: ſed turrigeros elephantorum mi- 'ramur humeros, taurorumque colla, et truces in ſublime jactus, 'tigrium rapinas, leonum jubas, cum rerum natura nuſquam magis 'quam in minimis, tota ſit.' Plin. ibid.

'in

'in the leaſt things.' For which reaſon he in-
'treats his readers, as I do mine, 'that becauſe
'they ſlighted many of the things themſelves
'which he took notice of, they would not
'therefore diſdainfully condemn his accounts
'of them, ſince ſaith he, in the contemplation
'of nature, nothing ought to ſeem ſuperfluous.'

THUS that eminent naturaliſt hath made his own, and my excuſe too; the force and verity whereof will farther appear, by what I ſhall ſay of theſe animals, which (as deſpicable as they have been, or perhaps may be thought) we ſhall find as exquiſitely contrived, and curiouſly made for that place and ſtation they bear in the world, as any other part of the animal world. For if we conſider the innumerable variety of their ſpecies, the prodigious numbers of individuals, the ſhape and make of their little bodies, and every part thereof, their motion, their inſtincts, their regular generation and production; and, to name no more, the incomparable beauty and luſtre of the colours of many of them, what more admirable and more manifeſt demonſtration of the infinite Creator, than even this little contemned branch of the animal world! But let us take a ſhort view of particulars.

CHAP.

CHAP. II.

OF THE SHAPE AND STRUCTURE OF INSECTS.

LET us begin with the ſhape and fabric of their bodies: which, although it be ſomewhat different from that of birds, being particularly, for the moſt part, not ſo ſharp before, to cut and make way through the air, yet is better adapted to their manner of life. For, conſidering that there is little neceſſity of long flights, and that the ſtrength and activity of their wings doth much ſurpaſs the reſiſtance their bodies meet with from the air, there was no great occaſion their bodies ſhould be ſo ſharpened before. But the condition of their food, and the manner of gathering it, together with the great neceſſity of accurate viſion, by that admirable proviſion made for them by the reticulated cornea of their eyes; theſe things, I ſay, as they required a larger room, ſo were a good occaſion for the largeneſs

largeneſs of the head, and its amplitude before. But for the reſt of their body, all is well made, and nicely poiſed for their flight, and every other of their occaſions.

AND as their ſhape, ſo the fabric and make of their bodies is no leſs accurate, admirable, and ſingular; nor built throughout with bones, and covered with fleſh and ſkin, as in moſt other animals; but covered with a curious mail of a middle nature [i], ſerving both as ſkin and bone too, for the ſhape, as well as ſtrength and guard, of the body; and as it were on purpoſe to ſhew, that the great contriver of nature is not bound up to one way only.

[i] 'Inſecta non videntur nervos habere, nec oſſa, nec ſpinas, 'nec cartilaginem, nec pinguia, nec carnes, nec cruſtam quidem 'fragilem, ut quædam marina, nec quæ jure dicatur cutis: ſed 'mediæ cujuſdam inter omnia hæc naturæ corpus,' &c. Plin. Nat. Hiſt. l. 11 c. 4.

CHAP.

CHAP. III.

OF THE EYES AND ANTENNÆ OF INSECTS.

TO this laſt-mentioned guard, we may add that farther guard provided in the eyes and antennæ. The ſtructure of the eye is, in all creatures, an admirable piece of mechaniſm; but that obſervable in the eyes of inſects ſo peculiar, that it muſt needs excite our admiration: fenced with its own hardneſs, yea, even its own accurate viſion, is a good guard againſt external injuries; and its cornea, or outward coat, all over beſet with curious, tranſparent, lenticular inlets[k], enabling thoſe creatures to ſee, no doubt, very

[k] The cornea of flies, waſps, &c. are ſo common an entertainment with the microſcope, that every body knows it is a curious piece of lattice-work. In which this is remarkable, that every foramen is of a lenticular nature; ſo that we ſee objects through them topſey-turvey, as through ſo many convex glaſſes: yea, they become a ſmall teleſcope, when there is a due focal diſtance between them and the lens of the microſcope.

very accurately every way, without any interval of time or trouble to move the eye towards objects.

AND as for the other part, the antennæ, or feelers, whatever their use may be in cleaning the eyes, or other such like use; they are, in all probability, a good guard to the eyes and head, in their walk and flight, enabling them, by the sense of feeling, to discover such annoyances, which, by their proximity, may perhaps escape the reach of the eyes and sight[1]. Besides which, they

This lenticular power of the cornea, supplies, as I imagine, the place of the chrystalline, if not of the vitreous humour too, there being neither of those humours that I could ever find (although, for truth's sake, I confess I have not been so diligent as I might in this inquiry;) but instead of humours and tunics, I imagine that every lens of the cornea hath a distinct branch of the optic nerve ministering to it, and rendering it as so many distinct eyes. So that as most animals are binocular, spiders, for the most part octonocular, and some, (as Mr. Willoughby thought, Raii Hist. Insect. p. 12.) senocular; so flies, &c. are multocular, having as many eyes as there are perforations in their cornea. By which means, as other creatures are obliged to turn their eyes to objects, these have some or other of their eyes ready placed towards objects, nearly all round them: thus particularly it is in the dragon-fly, libella, the greatest part of whose head is possessed by its eyes: which is of excellent use to that predacious insect, for the ready seeing and darting at small flies all round it on which it preys.

[1] It is manifest, that insects clean their eyes with their fore legs, as well as antennæ. And considering, that as they walk along, they are perpetually feeling, and searching before them, with their feelers,

they are a curious piece of workmanſhip, and in many, a very beautiful piece of [m] garniture to the body.

feelers, or antennæ; therefore I am apt to think, that beſides wiping and cleaning the eyes, the uſes here named may be admitted. For as their eyes are immoveable, ſo that no time is required for the turning their eyes to objects; ſo there is no neceſſity of the retina, or optic nerve being brought nigher unto, or ſet farther off from the cornea, which would require time, as it is in other animals: but their cornea and optic nerve, being always at one and the ſame diſtance, are fitted only to ſee diſtantial objects, but not ſuch as are very nigh: which inconvenience the feelers obviate, leſt it ſhould be prejudicial, in occaſioning the inſect to run its head againſt any thing.

And that this, rather than the wiping the eyes, is the chief uſe of the feelers, is farther manifeſt from the antennæ of the fleſh-fly, and many other inſects, which are ſhort, and ſtrait, and incapable of being bent unto, or extended over the eyes: as alſo from others enormouſly long, ſuch as thoſe of the capricorni, or goat-chafers, the cadew-fly, and divers others, both beetles and flies.

[m] The lamellated antennæ of ſome, the clavellated of others, the neatly articulated of others, the feathered and divers other forms of others, of the ſcarab, papilionaceous gnat, and other kinds, are ſurpriſingly beautiful, when viewed through a microſcope. And in ſome, thoſe antennæ diſtinguiſh the ſexes: as in the gnat-kind, all thoſe with tufts, feathers, and bruſh-horns, are males; thoſe with ſingle-ſhafted antennæ, are females.

CHAP. IV.

OF THE PARTS AND MOTION OF INSECTS.

FROM the head pafs we to the members, concerned in their motion. And here we have a copious fubject, if I was minded to expatiate. I might take notice of the admirable mechanifm in thofe that creep; the curious oars in thofe amphibious infects that fwim and walk[n]; the incomparable provifion made in the feet of fuch as walk, or hang upon fmooth furfaces[o]; the great

[n] All the families of hydrocanthari, notonecti, &c. have their hindmoft legs made very nicely, with commodious joints, and briftles on each fide towards the end, ferving for oars to fwim; and then, nearer the body, are two ftiff fpikes, to enable them to walk, when occafion is.

[o] I might here name divers flies, and other infects, who, befides their fharp hooked nails, have alfo fkinny palms to their feet, to enable them to ftick on glafs, and other fmooth bodies, by means of the preffure of the atmofphere. But becaufe the example will illuftrate another woik of nature, as well as this, I fhall chufe a fingu-

 lar

great ſtrength and ſpring in the legs of ſuch as leap [p]; the ſtrong and well-made feet and talons of ſuch as dig [q]: and, to name no more, the admirable faculty of ſuch as cannot fly, to convey themſelves with ſpeed and ſafety, by the help of their webs [r], or ſome other artifice, to make their

lar piece of mechaniſm, in one of the largeſt ſorts of hydrocanthari. Of theſe large ones there are two ſorts, one largeſt, all black, with antennæ handſomely emboſſed at the ends. The other ſomewhat leſſer, hardly ſo black, with capillary antennæ; the forehead, edges of the vaginæ, and two rings on the thorax, of a tawny colour. The female hath the vaginæ prettily furrowed, the male ſmooth. But that which is moſt to our purpoſe in this male, is a flap, or hollowiſh cap near the middle joint of the fore-legs, which, when clapped on the ſhoulders of the female in coitu, ſticks firmly thereon, after the manner, as I have ſeen boys carry heavy ſtones, with only a wet piece of leather clapped on the top of the ſtone.

[p] Thus graſhoppers and crickets have brawny ſtrong thighs, with long, ſlender, but ſtrong legs, which enable them to leap with great agility and ſtrength.

[q] I have wondered to ſee with what great quickneſs, art, and ſtrength, many veſpæ-ichneumons, wild-bees, and beetles, perforate the earth, yea, even wood itſelf: but the moſt remarkable animal in this way, is the mole-cricket, in book iv. chap. 13.

[r] I have, with pleaſure, often ſeen ſpiders dart out their webs, and ſail away by the help thereof. For the manner of which, ſee Mr. Lowthorp's Abridgm. vol. ii. p. 724. from Dr. Liſter and Dr. Hulſe, who both claimed the diſcovery thereof. And both do ſeem to have hit thereupon, without any fore-knowledge of what each other hath diſcovered, as is ſaid in the laſt cited place, and as I more particularly find by Mr. Ray's Philoſo. Letters, printed Anno 1718, p. 95, &c. By which alſo I find, the two ingenious doctors were very modeſt in their claims, and very amicable in the matter. In one of Dr. Liſter's to Mr. Ray, he thinks there is a fair hint of the

their bodies lighter than the air[s]: these, and a multitude of other such things as these, I might, I say,

the darting of spiders in Aristot. Hist. An. l. 9. c. 39. And in Pliny, l. 11. c. 24. But for their sailing, that, the ancients are silent of, and he thinks it was first seen by him. And in another letter, Jan. 20. 1670, speaking of the height spiders are able to fly, he saith, 'The last October, &c. I took notice that the air was very 'full of webs. I forthwith mounted to the top of the highest steeple 'on the Minster, (in York,) and could thence discern them yet exceeding high above me. Some that fell, and were entangled upon 'the pinnacles, I took, and found them to be lupi; which kind seldom or never enter houses, and cannot be supposed to have taken 'their flight from the steeple.'

[s] There are, I imagine, divers animals, as well as spiders, that have some way of conveyance, as little known to us, as that of spiders formerly was. Thus the squillulæ, pulices arborescentes, and microscopical animalcules of the stagnating waters, so numerous in 'them, as to discolour sometimes the waters, and make them look as if they were tinged red, yellow, or green, or covered with a thick green scum; all which is nothing but animalcules of that colour. That these creatures have some way of conveyance, I conclude, because most stagnating waters are stocked with them, new pits and ponds, yea, holes and gutters on the tops of houses and steeples. That they are not bred there by equivocal generation, every ingenious, considering philosopher will grant; that they have not legs for travelling so far, is manifest from inspection: and therefore I am apt to think, that they have some faculty of inflating their bodies, or darting out webs, and making their bodies buoyant, and lighter than air; or their bodies, when dry, may be lighter than air, and so they can swim from place to place; or the eggs of such as are oviparous, may be light enough to float in the air. But then the viviparous (as my late ingenious friend, Mr. Charles King, shewed me the pulices aquatices arborescentes are; these, I say,) cannot be t'is way accounted for. The cause of these latter suspicions was, that in the summer months, I have seen the pulices arborescentes, and

I say, take notice of, as great evidences of the infinite Creator's wisdom: but lest I should be too tedious, I will confine my observations to the legs and wings only. And these, at first view, we find to be incomparably fitted up for their intended service, not to overload the body, nor in the least to retard it; but to give it the most proper and convenient motion. What, for example, can be better contrived, and made for this service than the wings! Distended and strengthened by the finest bones, and these covered with the finest and lightest membranes, some of them adorned with neat and beautiful feathers[t]; and many of them provided with the finest articulations, and foldings, for the wings to be withdrawn, and neatly laid up in their vaginæ, and cases, and again readily extended for flight[v].

AND

and the green scum on the waters, nothing but animalcules, as I said, lie in a manner dry on the surface of the waters; at which time, as I have shewn in book iv. chap. 11. those animalcules copulate; and, perhaps, they may, at the same time, change their quarters, and seek out new habitations for their numerous offspring, as well as themselves.

[t] It is well known to all persons any way conversant in microscopical observations, that these elegant colours of moths, and butterflies, are owing to neat and well-made feathers, set with great curiosity and exactness in rows, and good order.

[v] All that have elytra, scarabs, (who have whole elytra, or reaching to the podex, or the Ἡμικολεόπτεροι, such as ear-wigs, and

 staphilini

AND then for the poifing of the body, and keeping it upright, and fteady in flight, it is an admirable artifice and provifion for this purpofe; in fome, by four wings [u]; and in fuch as have but two, by pointels, and poifes placed under the wings, on each fide of the body.

AND laftly, it is an amazing thing to reflect upon the furprizing minutenefs, art, and curiofity

ftaphilini of all forts,) do, by a very curious mechanifm, extend and withdraw their membranaceous wings, wherewith they chiefly fly; and it is very pretty to fee them prepare themfelves for flight, by thrufting out, and unfolding their wings, and again withdraw thofe joints, and neatly fold in the membranes, to be laid up fafely in their elytra or cafes. For which fervice the bones are well placed, and the joints miniftring thereunto are accurately contrived, for the moft compendious, and commodious folding up the wings.

[u] For the keeping the body fteady and upright in flight, it generally holds true, if I miftake not, that all the bipennated infects have poifes joined to the body, under the hinder part of their wings: but fuch as have four wings, or wings with elytra, none. If one of the poifes, or one of the leffer auxiliary wings be cut off, the infect will fly as if one fide over-balanced the other, until it falleth on the ground; fo if both be cut off they will fly aukwardly, and unfteadily, manifefting the defect of fome very neceffary part. Thefe poifes, or pointels, are, for the moft part, little balls, fet at the top of a flender ftalk, which they can move every way at pleafure. In fome they ftand alone, in others, as in the whole flefh-fly tribe, they have little covers or fhields, under which they lie and move. The ufe, no doubt, of thefe poifes, and fecondary leffer wings, is to poife the body, and to obviate all the vacillations thereof in flight; ferving to the infect, as the long pole, laden at the ends with lead, doth the rope-dancer.

As

riosity of the joints [w], the muſcles, the tendons, the nerves, neceſſary to perform all the motions of the legs, the wings, and every other part. I have already mentioned this in the larger animals; but to conſider, that all thoſe things concur in minute animals; even in the ſmalleſt mite; yea, the animalcules, that, without good microſcopes, eſcape our ſight; to conſider, I ſay, that thoſe minuteſt animals have all the joints, bones, muſcles, tendons, and nerves, neceſſary to that briſk and ſwift motion that many of them have, is ſo ſtupenduous a piece of curious art [x], as plainly manifeſteth the power and

[w] As all the parts of animals are moved by the help of theſe; ſo there is no doubt but the minuteſt animals have ſuch like parts: but the muſcles and tendons of ſome of the larger inſects, and ſome of the leſſer too, may be ſeen with a microſcope.

[x] The minute curioſities, and inimitable fineries, obſervable in thoſe leſſer animals, in which our beſt microſcopes diſcover no botch, no rude ill-made work, contrary to what is in all artificial works of man, do they not far more deſerve our admiration, than thoſe celebrated pieces of human art? Such as the cup made of a pepper-corn, by Oſwald Nerlinger, that held twelve hundred ivory cups, all gilt on the edges, and having each of them a foot, and yet affording room for four hundred more, in the Ephem. Germ. T. 1. Addend. ad obſ. 13. Such alſo was Phæton in a ring, which Galen thus reflects upon, when he ſpeaks of the art and wiſdom of the Maker of animals, particularly ſuch as are ſmall: 'Quanto,' ſaith he, 'ipſum minus fuerit, tanto majorem admirationem tibi excitabit; quod declarant opifices cum in corporibus parvis aliquid 'in-

and wisdom of the infinite contriver of those inimitable fineries. But having named those minute animals, why should I mention only any one part of their bodies, when we have, in that little compass, a whole and complete body, as exquisitely formed, and, as far as our scrutiny can possibly reach, as neatly adorned, as the largest animal! Let us consider, that there we have eyes, a brain, a mouth, a stomach, entrails, and every other part of an animal body, as well as legs and feet; and that all those parts have each of them their necessary apparatus of nerves, of various muscles, and every other part that other insects have; and that all is covered and guarded with a well-made tegument, beset with bristles, adorned with neat imbrications, and many other fineries. And lastly, let us consider in how little compass all art and curiosity may lie, even in a body many

'insculpant: cujus generis est quod nuper quidem in annulo 'Phaetonta quatuor equis invectum sculpsit. Omnes enim equi 'frenum, os, et dentes anteriores habebant,' &c. And then having taken notice, that the legs were no bigger than those of a gnat, he shews that their make did not come up to those of the gnat; as also, saith he, 'Major adhuc alia quaedam esse videtur artis ejus, 'qui pulicem condidit. vis atque sapientia, quod, &c. Cum igitur 'ars tanta in tam abjectis animalibus appareat,—quantam ejus vim 'ac sapientiam in praestantioribus inesse putabimus?' Galen. de usu Part. l. 17. c. 1. fin.

times

times lefs than a fmall grain of fand[y]; fo that the leaft drop of water can contain many of them, and afford them alfo fufficient room to dance and frifk about in[z].

HAVING furveyed as many of the parts of infects as I care to take notice only of; I fhall, in the next place, fay fomewhat of their ftate, and circumftances of life. And here I fhall take notice only of two things, which have been only hinted at before; but will deferve more particular confideration here, as being acts of a wonderful inftinct; namely, their fecurity of themfelves againft winter; and their fpecial care of preferving their fpecies.

[y] It will in fome meafure appear, how wonderfully fome minute microfcopical animalcules are, by what follows in the next note. But becaufe more particular examples would be endlefs, I fhall refer to the obfervations of Mr. Lewenhoeck, and others, in the Philof. Tranf. and elfewhere.

[z] It is almoft impoffible, by reafon of their perpetual motion, and changing places, to count the number of the animalcules, in only a drop of the green fcum upon water; but I guefs I have fometimes feen not fewer than one hundred frifking about in a drop no bigger than a pin's head. But in fuch a drop of pepper-water, a far greater number; thefe being much lefs than thofe.

CHAP.

CHAP. V.

THE SAGACITY OF INSECTS TO SECURE THEMSELVES AGAINST WINTER.

IT is an extraordinary act of instinct and sagacity, observable in the generality of the insect-tribe, that they all take care to secure themselves, and provide against the necessities of winter: that when the distresses of cold and wet force them, they should retire to warm and dry places of safety, is not strange; but it is a prodigious act of the infinite Conservator's care, to enable some to live in a different kind of insect-state; others to live, as without action, so without food; and others that act and eat, to lay up in summer sufficient provisions against the approaching winter. Some, I say, live in a different state; for having sufficiently fed, nourished, and bred up themselves to the perfection of their vermicular nympha-state, in the summer-months,

months, they then retire to places of ſafety, and there throw off their nympha, and put on their aurelia, or chryſalis-ſtate, for all the winter, in which there are no occaſions for food. This is the conſtant method of many families of the inſect-tribe [a].

But there are others, and ſome of them in their moſt perfect ſtate too, that are able to ſubſiſt in a kind of torpitude, or ſleeping ſtate, without any food at all; by reaſon, as there is no action, ſo no waſte of body, no expence of ſpirits, and therefore no need of food [b].

But

[a] It would be endleſs to enter into particulars here, becauſe all the papilionaceous, fleſh and ichneumon-fly tribes, and all others that undergo the nympha and aurelia-ſtate, between that of the egg and the mature-ſtate, which are very numerous, appertain to this note. For a ſample thereof only, I ſhall take what ſome may think a mean one, but if conſidered, deſerves our admiration, and that is, the ſagacity of the white-butter-fly caterpillar, which having fed itſelf its due time, then retires to places of ſecurity. I have ſeen great trains of them creeping up the walls and poſts of the next houſes, where, with the help of ſome cob-webs, like filaments, they hang themſelves to the cielings, and other commodious places, and then become aureliæ; in which ſtate and places they hang ſecure from the wet and cold, till the ſpring, and warmer months, when they are tranſmuted into butter-flies.

[b] I ſhall not name any of the particular ſpecies of inſects which live in this ſtate, becauſe they are very numerous, but only remark two

But for others that move and act, and need food, it is a prodigious instinct and foresight the Creator hath imprinted on them, to lay up sufficient food in summer for the winter's [c] necessities and occasions. And it is very pretty to see with what unwearied diligence all hands are at

two things observable in their sagacity in this matter: 1. That they are not driven by stress of weather to their retirement, but seem as naturally to betake themselves thereto, as other animals do to rest and sleep. For before the approach of cold weather, towards the end of summer, we may see some kinds of them flocking together, in great numbers, within doors, as swallows do a little before they leave us, as if they were making ready for their winter's rest. 2. That every species betakes itself to a proper convenient receptacle; some under the waters, to the bottom of ponds; some under the earth, below the frost; some under timber, stone, &c. lying on the ground; some into hollow trees, or under the bark, or in the wood; some into warm and dry places; and some into dry alone.

[c] There are not many kinds that thus provide their food beforehand. The most remarkable, are the ant and the bee; concerning the first of which, Origen hath this remark, viz. 'De solertia formicarum, venturæ hyemi mature prospicientium, sibique invicem sub onere fessis succurrentium; quodque fruges arrosas condunt, ne rursus enascantur, sed per annum alimento sint, non ratiocinationem formicarum in causa debemus credere, sed almam matrem naturam bruta quoque sic ornantem, ut etiam minimis addat sua quædam ingenia.' Orig. cont. Cels. l. 4.

But as for wasps, hornets, bumble-bees, and other wild-bees, vespæ-ichneumons, and divers others that carry in materials for nests and food; this is only for the service of their generation, for hatching their eggs, and nourishing their young, not for supplies in winter; for they all forsake their nests towards winter; and retire to other quarters, living, I conceive, without food all that time.

work for that purpofe, all the warmer months. Of this the Holy Scripture itfelf gives us an inftance in the ant, calling that little animal 'exceeding wife,' Prov. xxx. 24. And the reafon is, ver. 25. 'The ants are a people not 'ftrong, yet they prepare their meat in fum-'mer.' And therefore Solomon fends the fluggard to this little contemptible creature, to learn wifdom, forefight, care, and diligence, Prov. vi. 6, 7, 8. 'Go to the ant, thou fluggard, con-'fider her ways, and be wife: which having no 'guide, overfeer, or ruler, provideth her meat 'in the fummer, and gathereth her food in the 'harveft.'

To this fcriptural example, give me leave to anticipate, and fubjoin an obfervation of the farther great wifdom of this little creature; and that is their unparalleled Στοργὴ, their tendernefs, fagacity, and diligence, about their young [d]. It

[d] 'Hos vermiculos [formicarum ova vulgo vocatos] incredibili 'Στοργῇ et cura formicæ educant, fummamque dant operam, ne vel tan-'tillum, quod fpectet eorum vermiculorum educationem atque nutri-'tionem, omittant: quem in finem fere femper eofdem ore circumpor-'tant fecum, ne ulla eos lædat injuria. In mufeo meo nonnullas iftius 'generis formicas, vitro terra repleto, conclufas cum vermiculis iftis 'adfervabam: ibi non fine jucunditate fpectabam, quo terra fieret in 'fuperficie ficcior, eo profundius formicas cum fætibus fuis prorepere: 'cum vero aquam adfunderem, vifu mirificum erat, quanto effectu, 'quanta folicitudine, quanta Στοργῇ omnem in eo collocarent operam, 'ut

It is very diverting, as well as admirable to see, with what affection and care they carry about their young in their mouths, how they expose themselves to the greatest dangers, rather than leave their young exposed or forsaken; how they remove them from place to place in their little hills, sometimes to this part, sometimes to that, for the benefit of convenient warmth, and proper moisture; and then again withdraw, and guard them against rain and cold. Now, that this great wisdom which the Scriptures attri-

'ut foetus suos sicciore et tuto loco reponerent. Sæpius vidi, cum 'aliquot diebus aqua caruissent, atque cum affuso tantillo aquæ 'teram illum humectarem, e vestigio a formicis fœtus suos eo loci 'fuisse allatos, quos ibi distincte conspiciebam moveri atque sugere 'humorem. Multoties fui conatus, ut eos vermiculos ipse educa-'rem, at semper conatum fefellit eventus: neque ipsas formicarum 'nymphas alimenti jam non indigas unquam sine ipsis formicis po-'tui potu artificiali excludere.' J. Swammerd. Epilog. ad Hist. Insect. p. 153.

Sir Edward King, who was very curious in examining the generation of ants, observes their great care and diligence, 1. About their sperm, or true eggs, which is a fine white substance, like sugar, which they dilligently gather into a heap, when scattered, and on which they lie in multitudes, I suppose, by way of incubation. 2. I have observed, saith he, in summer, that in the morning they bring up those of their young, called ant eggs, towards the top of the bank; so that you may, from 10 in the morning, until 5 or 6 in the afternoon, find them near the top—for the most part on the south-side the bank. But towards 7 or 8 at night, if it be cool, or likely to rain, you may dig a foot deep before you can find them. Phil. Transf. N° 23. or Mr. Lowthorp's Abrigment volume 2. page 7, and 9.

The

tribute unto, and is difcernible in this little animal, is owing only to the inftinct, or infufions of the great Confervator of the world, is evident, becaufe either this wifdom, thought, and forecaft, is an act of the animal itfelf, or of fome other being that hath wifdom. But the animal being irrational, it is impoffible it can be its own act, but muft be derived, or received from fome wife being. And who? What can that be, but the infinite Lord, confervator, and governor of the world!

CHAP. VI.

OF THE CARE OF INSECTS ABOUT THEIR YOUNG.

THE other notable inſtinct I am to treat of, is the peculiar art and care of the inſect-tribe, about the preſervation of their ſpecies. Here I might ſpeak of many things, but I have occaſionally mentioned divers of them before, under ſome or other of the general heads, and therefore ſhall fix only upon two things relating to their ſpecial art and care about the production [e] of their young, which have not been ſo particularly ſpoken to as they deſerve.

[e] The doctrine of aequivocal generation, is at this day ſo ſufficiently exploded by all learned philoſophers, that I ſhall not enter the diſpute, but take it for granted, that all animals ſpring from other parent-animals. If the reader hath any doubt about it, I refer him to Seigneur Redi de Gen. Inſect. and Mr. Ray's Wiſdom of God, &c. p. 344. See alſo before, book iv. chap. 15.

One thing is their fingular providence for their young, in making or finding out fuch proper receptacles and places for their eggs and feed, as that they may receive the advantage of a fufficient incubation, and that the young when produced, may have the benefit of proper and fufficient food for their nurture and education, till they are able to fhift for themfelves. It is admirable to fee with what diligence and care the feveral fpecies of infects lay up their eggs, or fperm, in their feveral proper places; not all in the waters, in wood, or vegetables; but thofe whofe fubfiftence is in the waters [f], in the water; thofe to whom flefh is a proper food, in flefh [g]; thofe to whom the fruits [h] or leaves of vege-

[f] It would be endlefs to fpecify the various fpecies of infects, that have their generation in the waters; and therefore I fhall only obferve of them, 1. That their eggs are always laid up with great care, and in good order. And alfo, 2. Where proper and fufficient food is. 3. That in their nympha-ftate in the waters, they have parts proper for food and motion; and in many, or moft of them, very different from what they have in their mature ftate; a manifeft argument of the Creator's wifdom and providence.

[g] As Seigneur Redi was one of the firft that made it his bufinefs to difcard anomalous generation, fo he tried more experiments relating to the vermination of ferpents, flefh, fifh, putrified vegetables; and in fhort, whatever was commonly known to be the nurfery of maggots, more, I fay, probably, than any one hath done fince. And in all his obfervations, he conftantly found the maggots to turn to aureliæ, and thefe into flies. But then, faith he, 'Dubitare cœpi 'utrum

'utrum omne hoc vermium in carne genus, ex solo muscarum 'semine, an ex ipsis putrefactis carnibus oriretur, tantoque magis, 'confirmabar in hoc meo dubio, quanto in omnibus generationibus '—sæpius videram, in carnibus, antequam verminare inciperent, 'resediſſe ejusdem ſpeciei muſcas, cujus propago poſtea naſcebatur.' Upon this he tells us, he put fiſh, fleſh, &c. into pots, which he covered cloſe from the flies with paper, and afterwards, for the free air-ſake, with lawn, whilſt other pots were left open, with ſuch like fleſh, &c. in them; that the flies were very eager to get into the covered pots; and that they produced not one maggot, when the open ones had many, Fr. Redi de Gener. Inſect.

Among the inſects that come from the maggots he mentions, he names culices. Now, from the moſt critical obſervations I have made, I never obſerved any ſort of gnat to come from putrified fleſh, vegetables, or any other thing he taxeth them with. So that either he means by culex, ſome fly that we call not by the name of gnat; or elſe their gnats in Italy vary in their generation from ours in England. For among above thirty, near forty, diſtinct ſpecies of gnats that I have obſerved about the place where I live, I never found any to lay their eggs in fleſh, fiſh, &c. but the largeſt ſort, called, by Aldrovand, culices maximi, by Swammerdam, tipulæ terreſtres, lay their eggs in meadows, &c. under the graſs; one of the larger middle ſort, in dead beer, yeaſt, &c. lying on the tops, or in the leaks of bear-barrels, &c. and all the reſt, as far as ever I have obſerved, lay and hatch in the waters.

The generation of the ſecond of theſe being akin to ſome of the foregoing inſtances, and a little out of the way, may deſerve a place here. This gnat lays its eggs commonly in dead beer, &c. as I ſaid, and probably in vinegar, and other ſuch liquors. Some time after which, the maggots are ſo numerous, that the whole liquor ſtirreth as if it was alive; being full of maggots, ſome larger, ſome ſmaller; the larger are the offspring of our gnat, the ſmaller, of a ſmall dark coloured fly, tending to reddiſh, frequent in cellars, and ſuch obſcure places. All thoſe maggots turn to aureliæ, the larger of which, of a tan-colour, turn to our gnat. This gnat is of the unarmed kind, having no ſpear in its mouth: its head is larger than that of the common gnats, a longer neck, ſhort-jointed antennæ, ſpotted wings, vegetables are food, are accordingly reposited,

wings, reaching beyond its slender alvus; it is throughout of a brown colour, tending to red, especially in the female: the chief difference between the male and female is, as in other gnats, yea, most insects, the male is less than the female, and hath a slender belly, and its podex not so sharp as the female's is.

[h] The insects that infest fruits, are either of the ichneumon-fly kind, or phalænæ. Plumbs, pease, nuts, &c. produce some other ichneumon-fly. That generated in the plumb is black, of a middle size, its body near three tenths of an inch long, its tail not much less, consisting of three bristles, wherewith it conveys its eggs into fruits: its antennæ, or horns, long, slender, recurved; its belly longish, tapering, small towards the thorax; legs reddish; wings membranaceous, thin, and transparent, in Numb. 4. which is one characteristic of the ichneumon-fly.

The pease ichneumon-fly is very small, wings large, reaching beyond the podex; antennæ long; alvus short, shaped like an heart, with the point towards the anus; it walketh and flieth slowly: no tail appears as in the former; but they have one lieth hidden under the belly, which they can at pleasure bend back to pierce pease when they are young and tender, and other things also, as I have reason to suspect, having met with this, as indeed the former two, in divers vegetables.

Pears and apples I could never discover any thing to breed in, but only the lesser phalæna, about four tenths of an inch long, whitish underneath, greyish-brown above, dappled with brown spots, inclining to a dirty red, all but about a third part at the end of the wings, which is not grey, but brown, elegantly striped with wavey lines, of a gold colour, as if gilt; its head is small, with a tuft of whitish brown in the forehead; antennæ smooth, moderately long. The aurelia of this moth is small, of a yellowish brown. I know not what time they require for their generation out of boxes; but those I laid up in August, did not become moths before June following.

ſome in this fruit, ſome on this tree [i] ſome on that plant [k], ſome on another, and another; but conſtantly the ſame family on the ſame tree or plant, the moſt agreeable to that family. And as for others that require a conſtant and greater degree of warmth, they are accordingly provided by the parent-animal with ſome place in or about the body of other animals; ſome in the

[i] There are many of the phalænæ, and ichneumon-fly tribes, that have their generation on the leaves, or other parts of trees and ſhrubs, too many to be here reckoned up. The oak hath many very beautiful phalænæ, bred in its convolved leaves, white, green, yellow, brown, ſpotted prettily, and neatly dappled, and many more beſides; and its buds afford a place for caſes, and balls of various ſorts, as ſhall be ſhewn hereafter; its leaves expanded, miniſter to the germination of globular, and other ſpheroidical balls, and flat thecæ, ſome like hats, ſome like buttons excavated in the middle; and divers other ſuch like repoſitories, all belonging to the ichneumon-fly kind. And not only the oak, but the maple alſo, the white-thorn, the brier, privet, and indeed almoſt every tree and ſhrub.

[k] And as trees and ſhrubs, ſo plants have their peculiar inſect. The white butterfly lays its voracious offspring on cabbage-leaves; a very beautiful reddiſh ocellated one; its no leſs voracious black offspring, of an horrid aſpect, on the leaves of nettles; as alſo doth a very beautiful, ſmall greeniſh ichneumon-fly, in caſes on the leaves of the ſame plant: and to name no more, becauſe it would be endleſs, the beautiful ragwort-moth, whoſe upper wings are brown, elegantly ſpotted with red, and under wings edged with brown; theſe, I ſay, provide for their golden-ringed erucæ upon the ragwort-plant.

feathers

feathers of birds [l]; ſome in the hair of beaſts [m]; ſome in the very ſcales of fiſhes [n]; ſome in the noſe;

[l] Many, if not moſt ſorts of birds, are infeſted with a diſtinct kind of lice, very different from one another in ſhape, ſize, &c. For figures and deſcriptions of them, I ſhall refer to Signeur Redi of Inſects, See alſo Mouffet, l. 2. c. 23. Theſe lice lay their nits among the feathers of the reſpective birds, where they are hatched and nouriſhed; and, as Ariſtotle ſaith, would deſtroy the birds, particularly pheaſants, if they did not duſt their feathers. Loco infra citat.

[m] And as birds, ſo the ſeveral ſorts of beaſts have their peculiar ſorts of lice; all diſtinct from the two ſorts infeſting man: only the aſs, they ſay, is free, becauſe our Saviour rode upon one, as ſome think; but I preſume it is rather from the paſſage in Pliny, l. 11. c. 33. or rather Ariſt. Hiſt. Animal l. 3. c. 31. who ſaith, 'Quibus 'pilus eſt, non carent eodem [pediculo] excepto aſino, qui non 'pediculo tantum, verum etiam redivio immunis eſt.' And a little before, ſpeaking of thoſe in men, he ſhews what conſtitutions are moſt ſubject to them, and inſtanceth in Alcman the poet, and Pherecydes Syrius, that died of the pthiriaſis, or lowſy diſeaſe. For which foul diſtemper, if medicines are deſired, Mouffet de Inſect. p. 262. may be conſulted; who, in the ſame page, hath this obſervation, 'Animadverterunt noſtrates—ubi Aſores inſulas a tergo re'liquerint, pediculos confeſtim omnes tabeſcere: atque ubi eos 'reviſerint, iterum innumeros alios ſubito oriri.' Which obſervation is confirmed by Dr. Stubs. Vide Lowth. Abridgm. vol. 3. p. 558. And many ſeamen have told me the ſame.

[n] Fiſhes, one would think, ſhould be free from lice, by reaſon they live in the waters, and are perpetually moving in, and bruſhing through them; but yet they have their ſorts too.

Beſides which, I have frequently found great numbers of long ſlender worms in the ſtomach, and other parts of fiſh, particularly

 codfiſh,

nose [o]; some in the flesh [p]; yea, some in the very bowels,

codfish, especially such as are poor; which worms have worked themselves deeply into the coats and flesh, so that they could not easily be gotten out: so Aristotle saith of some fishes, 'Ballero et 'tilloni lumbricus innascitur, qui debilitat, &c. Chalcis vitio in- 'festatur diro, ut pediculi sub branchiis innati quam multi interi- 'mant.' Hist. An. l. 8. c. 20.

[o] Of insects bred in the nose of animals, those in the nostrils of sheep are remarkable. I have myself taken out not fewer at a time than twenty or thirty rough maggots, lying among the laminæ of the nostrils. But I could never hatch any of them, and so know not what animal they proceed from: but I have no great doubt, they are of the ichneumon-fly kind; and not improbably of that with a long tail, called triseta, whose three bristles seem very commodious for conveying their eggs into deep places.

I have also seen a rough whitish maggot, above two inches within the intestinum rectum of horses, firmly adhering thereto, that the hard dung did not rub off. I never could bring them to perfection, but suspect the side fly proceeds from it.

[p] In the backs of cows, in the summer months, there are maggots generated, which in Essex we call wornills; which are first only a small knot in the skin; and, I suppose, no other than an egg laid there by some insect. By degrees these knots grow bigger, and contain in them a maggot lying in a purulent matter: they grow to be as large as the end of one's finger, and may be squeeed out at a hole they have always open: they are round and rough, and of a dirty white. With my utmost endeavour and vigilance, I could never discover the animal they turn into; but as they are somewhat like, so may be the same as those in the note before.

In Persia, there are very long slender worms, bred in the legs, and other parts of men's bodies, 6 or 7 yards long.

In

In Philosophical Transactions, Mr. Dent, and Mr. Lewis, relate divers examples of worms taken out of the tongue, gums, nose, and other parts, by a woman at Leicester, which they were eye-witnesses of. These and divers others mentioned in the Transactions, may be seen together in Mr Lowthorp's Abridgm. vol. 3. p. 132.

'Narrat mihi vir fide dignus—Casp. Wendlant—se in Polonia, 'puero cuidam rustico duorum annorum, vermiculum album e 'palpebra extraxisse,—magnitudinis Erucæ.—Similem fere huic 'casum mihi [Schulzio] et D. Segero narravit hoc, Anno 1676, 'chirurgus noster Ant. Statlender, qui cuidam puero, ex aure, ex'traxit vermiculum talem, qualis in nucibus avellanis perforatis 'latitare solet, sed paulo majorem, coloris albissimi; alteri minores '5 ejusdem generis similiter ex aure: omnes aliquot horas super'vixerunt—vermiculos adhuc viventes oculis nostris vidimus.' Ephem. Germ. T. 2. obs. 245 ubi vermiculi Icon. Many other instances may be met with in the same tome. Obs. 147, 148, 154.

The worms in deer are mentioned often among ancient writers. Aristotle saith, Σκώληκας μέντοι πάντες ἔχουσιν, ἐν τῇ κεφαλῇ ζῶντας, 'They [deer] all have live worms in their heads, bred under the 'tongue, in a cavity near the vertebra on which the head is placed; 'their size not less than that of the largest maggots; they are bred 'altogether, in number about twenty.' Aristotle's Hist. of Animal. l. 2. c. 15.

To these examples may be added the generation of the ichneumon fly in the bodies of caterpillars, and other nymphæ of insects. In many of which, that I have laid up to be hatched in boxes, instead of papilios, &c. as I expected, I have found a great number of small ichneumon-flies, whose parent animal had wounded those nymphæ, and darted its eggs into them, and so made them the foster-mother of its young. More particulars of this way of generation may be seen in the great Mr. Willoughby's observations in Philos. Trans. N° 76. But concerning the farther generation of this insect, I have taken notice of other particulars in other places of those notes.

The

bowels [q], and inmoſt receſſes of the bodies of man

[q] The animals ordinarily bred in the ſtomach and guts, are the three ſorts of worms called lati, teretes, and aſcarides; concerning which, it would be irkſome to ſpeak in particular, and therefore I ſhall refer to Mouffet, lib. 2. cap. 31, 32, 33. Dr. Tyſon's anatomy of them in Mr. Lowthorp's Abrigment vol. 3. p. 121 Seigneur Redi's obſ. and others that have written of them.

As not only worms, but other creatures alſo are ſaid to be found in the ſtomach: inſtances of which are ſo innumerable, that I ſhall only ſelect a few related by perſons of the beſt credit. And firſt of all, by ſome of our own countrymen. Dr. Liſter, whoſe credit and judgment will hardly be queſtioned, gives an account of true caterpillars, vomited up by a boy of nine years old: and another odd animal by a poor man. Mr. Jeſſop, another very judicious, curious and ingenious gentleman, ſaw hexapods vomited up by a girl; which hexapods lived and fed for five weeks. See Lowth. ib. p. 135.

As to foreigners, it is a very ſtrange ſtory, but atteſted by perſons of great repute, of Catharina Geileria, that died in Feb. 1662. in the hoſpital of Altenburg, in Germany, who, for twenty years, voided by vomit and ſtool, toads and lizards, &c. Ephemer. Germ. T. 1. obſ. 103. See alſo the 109th obſervation of a kitten bred in the ſtomach, and vomited up; of whelps alſo, and other animals, bred in like manner. But I fear a ſtretch of fancy might help in ſome of thoſe laſt inſtances, in thoſe days when ſpontaneous generation was held, when the philoſophers ſeem to have more ſlightly examined ſuch appearances than now they do. But for the breeding of frogs or toads, or lacertæ aquaticæ, in the ſtomach, when their ſpawn happeneth to be drank, there is a ſtory in the ſecond tome of the Ephem. Germ. obſ. 56. that favours it, viz. 'In 'the year 1667, a butcher's man going to buy ſome lambs in the 'ſpring, being thirſty, drank greedily of ſome ſtanding water, which, 'a while after, cauſed great pains in his ſtomach, which grew worſe 'and worſe, and ended in dangerous ſymptoms. At laſt he thought

'ſome-man and other creatures[r]: and for others, to whom none of these methods are proper, but make themselves nests by perforations in the earth, in wood, or combs they build, or such like ways; it is admirable to see with what labour

'somewhat was alive in his stomach, and after that, vomited up three 'live toads; and so recovered his former health.'

Such another story Dr. Sorbait tells, and avoucheth it seen with his own eyes, of one that had a toad came out of an abscess, which came upon drinking foul water. Obs. 103.

[r] Not only in the guts, and in the flesh, but in many other parts of the body, worms have been discovered. One was voided by urine, by Mr. Mat. Milford, supposed to have come from the kidneys. Lowth ib. page 135. More such examples Mouffet tells of. Ibid. So the vermes cucurbitini are very common in the vessels in sheep's livers. And Dr. Lister tells of them, found in the kidney of a dog, and thinks that the snakes and toads, &c. said to be found in animal's bodies, may be nothing else. Lowth. ib. p. 120. Nay, more than all this: in Dr. Bern. Verzascha's sixth observation, there are divers instances of worms bred in the brain of man. One, a patient of his, troubled with a violent head-ach, and an itching about the nostrils, and frequent sneezing; who, with the use of a sneezing-powder, voided a worm, with a great deal of snot from his nose. A like instance he gives from Bartholine, of a worm voided from the nose of O. W. which he guesseth was the famous Olaus Wormius: another, from a countrywoman of Deitmarsh; and others in Tulpius, F. Hildanus, Schenckins, &c. These worms he thinks are undoubtedly bred in the brain: but what way they can come from thence, I cannot tell. Wherefore I rather think they are such worms as are mentioned before in note [o], and even that that was actually found in the brain of the Paris girl, when opened, I guess might be laid in the laminæ of the nostrils, by some of the ichneumon,

bour and care they carry in, and ſeal up proviviſions, that ſerve both for the production of their young, and alſo for their food and nurture when produced [a].

The other piece of remarkable art and care about the production of their young, is their curioſity and neatneſs in repoſiting their eggs, and in their nidification.

As to the firſt of which, we may obſerve, that great curioſity and nice order is generally ob-

ichneumon. or other inſect kind, and might gnaw its way into the brain, through the os cribriforme. Of this he tells us from Bartholine, 'Tandem cum tabida obiiſſet, ſtatim aperto cranio præſentes 'medici totam cerebelli ſubſtantiam, quæ ad dextram vergit, a reli- 'quo corpore ſejunctam, nigraque tunica involutam deprehenderunt: 'hæc tunica rupta, latentem vermem vivum, et piloſum, duobus 'punctis ſplendidis loco oculorum prodidit, ejuſdem fere molis cum 'reliqua cerebri portione, qui duarum horarum ſpatio ſupervixit.' B. Verzaſ. obſ. Medicæ, p. 16.

Hildanus tells us ſuch another ſtory, viz. 'Filius Theod, auſt der 'Roulen, Avunculi mei, diuturno vexabatur dolore capitis—— 'Deinde febricula et ſternutatione exorta, ruptus eſt abſceſſus circa 'os cribroſum—et vermis prorepſit.' By his figure of it, the maggot was an inch long, and full of briſtles. Fabri Hildan. Cent 1. obſ.

Galenus Wierus, phyſician to the Prince Jul. et Cleve, he ſaith, told him, that he had, at divers times, found worms in the gall-bladder in perſons he had opened at Duſſeldorp. Id. ib. obſ. 60.

[a] See before, book iv. chap. 13.

Some

ſerved by them in this matter. You ſhall always ſee their eggs laid carefully and commodiouſly up[t]. When upon the leaves of vegetables, or other materials on land, always glued thereon with care, with one certain end lowermoſt, and with handſome juxta-poſitions[u]. Or if in the waters, in neat and beautiful rows oftentimes, in that ſpermatic, gelatine matter, in which they are repoſited, and that matter carefully tied and faſtened in the waters, to prevent its diſſipation[w], or if made to float, ſo carefully ſpread and

[t] Some inſects lay up their eggs in cluſters, as in holes of fleſh, and ſuch places, where it is neceſſary they ſhould be crouded together; which, no queſtion, prevents their being too much dried up in dry places, and promotes their hatching. But,

[u] As for ſuch as are not to be cluſtered up, great order is uſed. I have ſeen upon the poſts and ſides of windows, little round eggs, reſembling ſmall pearl, which produced ſmall hairy caterpillars, that were very neatly and orderly laid. And, to name no more, the white-butterfly lays its neat eggs on the cabbage leaves in good order, always gluing one certain end of the egg to the leaf. I call them neat eggs, becauſe if we view them in a microſcope, we ſhall find them very curiouſly furrowed, and handſomly made and adorned.

[w] By reaſon it would be endleſs to ſpecify the various generation of inſects in the water, I ſhall therefore, becauſe it is little obſerved, take Pliny's inſtance of the gnat, a mean and contemned animal, but a notable inſtance of nature's work, as he ſaith.

The firſt thing conſiderable in the generation of this inſect, is, for the ſize of the animal, its vaſt ſpawn, being ſome of them above an inch long, and half a quarter diameter; made to float in the water, and tied to ſome ſtick, ſtone, or other fixed thing in the waters, by a ſmall and poiſed, as to ſwim about with all poſſible artifice.

And

ſmall ſtem, or ſtalk. In this gelatine, tranſparent ſpawn; the eggs are neatly laid; in ſome ſpawns in a ſingle, in ſome in a double ſpiral line, running round from end to end, as in Fig. 9. and 10; and tranſverſly, as in Fig. 8.

When the eggs are by the heat of the ſun, and warmth of the ſeaſon, hatched into ſmall maggots, theſe maggots deſcend to the bottom, and by means of ſome of the gelatine matter of the ſpawn, which they take along with them, they ſtick to ſtones, and other bodies at the bottom, and there make themſelves little caſes or cells, which they creep into and out of at pleaſure, until they are arrived to a more mature nympha-ſtate, and can ſwim about here and there, to ſeek for what food they have occaſion; at which time, they are a kind of red-worms, above half an inch long, as Fig. 11.

Thus far this mean inſect is a good inſtance of the Divine Providence towards it. But if we farther conſider, and compare the three ſtates it undergoes after it is hatched, we ſhall find yet greater ſignals of the Creator's management, even in theſe meaneſt of creatures: The three ſtates I mean, are its nympha vermicular ſtate, its aurelia, and mature ſtate, all as different as to ſhape and accoutrements, as if the inſect was three different animals. In its vermicular-ſtate, it is a red maggot, as I ſaid, and hath a mouth and other parts accommodated to food. In its aurelia-ſtate, it hath no ſuch parts, becauſe it then ſubſiſts without food; but in its mature, gnat-ſtate, it hath a curious well made ſpear, to wound and ſuck the blood of other animals. In its vermicular ſtate, it hath a worm like body, and ſomething analogous to fins or feathers, ſtanding erect near its tail, and running parallel with the body, by means of which reſiſting the waters, it is enabled to ſwim about by curvations, or flapping its body ſide-ways, this way and that, as in Fig. 12.

But

AND as to their other faculty, that of nidification, whether it be exerted by boring the earth or wood, or building themfelves cells [x], or fpinning and weaving themfelves cafes and webs, it is all a wonderful faculty of thofe poor little animals, whether we confider their parts wherewith they work, or their work itfelf. Thus thofe who perforate the earth, wood, or fuch like, they have their legs, feet, mouth, yea, and whole body, accommodated to that fervice; their mouth exactly formed to gnaw thofe handfome round holes, their feet, as well made to fcratch and bore [y], and their body handfomely turned and fitted to follow. But for fuch as build or fpin themfelves nefts, their art juftly bids defiance to the moft ingenious artift among men, fo much as tolerably to copy the nice geomertical

But in its aurelia-ftate, it hath a quite different body, with a club-head, (in which the head, thorax, and wings of the gnat are inclofed) a flender alvus, and a neat finny tail, ftanding at right angles with the body, quite contrary to what it was before; by which means, inftead of eafy flapping fideways, it fwims by rapid, brifk jirks, the quite contrary way; as is in fome meafure reprefented in Fig. 13. But when it becomes a gnat, no finny-tail, no club-head, but all is made in the moft accurate manner for flight and motion in the air, as before it was for the waters.

[x] See book iv. chap. 13.

[y] Thus the moths and other parts of the ichneumon-wafps, in book iv. chap. 13. So the feet of the gryllotalpa.

geometrical combs of ſome [z], the earthen cells of others, or the webs, nets, and caſes [a] woven by others. And here that natural glue [b] which their bodies afford ſome of them to conſolidate their work, and combine its materials together, and

[z] See the laſt cited places.

[a] Of the textrine art of the ſpider, and its ſerving to that purpoſe, ſee the laſt cited place.

Beſides theſe, caterpillars, and divers other inſects, can emit threads, or webs, for their uſe. In this their nympha-ſtate, they ſecure themſelves from falling, and let themſelves down from the boughs of trees, and other high places, with one of theſe threads. And in the caſes they weave, they ſecure themſelves in their aurelia-ſtate.

And not only the offspring of the phalæna tribe, but there are ſome of the ichneumon-fly kind alſo, endowed with this textrine art. Of theſe I have met with two ſorts; one that ſpun a milk-white, long, round, ſilken web, as big as the top of one's finger, not hollow within, as many are, but filled throughout with ſilk. Theſe are woven round bents, ſtalks of ribwort, &c. in meadows. The other is a lump of many yellow, ſilken caſes, ſticking confuſedly together on poſts, under coleworts, &c. Theſe webs contain in them ſmall, whitiſh maggots; which turn to a ſmall, black ichneumon-fly, with long, capillary antennæ; tan coloured legs; long wings reaching beyond their body, with a black ſpot near the middle; the alvus like an heart; and in ſome, a ſmall ſetaceous tail. Some of theſe flies were of a ſhining, beautiful green colour. I could not perceive, any difference, at leaſt not ſpecifical, between the flies coming from thoſe two productions.

[b] I have often admired how waſps, hornets, ichneumon-waſps, and other inſects that gather dry materials for building their neſts, have

and which in others can be darted out at pleaſure, and ſpun and woven by them into ſilken balls [c] or webs: I ſay, this ſo peculiar, ſo ſerviceable a material, together with the curious ſtructure of all parts miniſtering to this textrine power, as mean a buſineſs as it may ſeem, is ſuch as may juſtly be accounted among the noble deſigns and works of the infinite Creator and Conſervator of the world.

In the laſt place, there is another prodigious faculty, art, cunning, or what ſhall I call it? that others of thoſe little animals have, to make even nature itſelf ſerviceable to their purpoſe; and

have found a proper matter to cement and glue their combs, and line their cells; which we find always ſufficiently context and firm. But in all probability, this uſeful material is in their own bodies; as it is in the tinea veſtivora, the cadew-worm, and divers others. Goedart obſerves of his eruca, Num. xx. 6. that fed upon ſallow-leaves, that it made its cell of the comminuted leaves, glued together with its own ſpittle. 'Hæc pulveris aut arenæ inſtar comminuit, ac pituitoſo quodam ſui corporis ſucco ita maceravit, ut inde accommodatum ſubeundæ mutationi inſtanti locum ſibi exſtruxerit. Domuncula hæc a communi ſalicum ligno nihil differre videbantur, niſi quod longe eſſent duriora, adeo ut cultro vix diſrumpi poſſent.'

[c] 'An ingenious gentlewoman of my acquaintance, wife to a learned phyſician, taking much pleaſure to keep ſilk worms, had once the curioſity to draw out one of the oval caſes, which the ſilken worm ſpins—into all the ſilken-wire it was made up of, which to the great wonder as well of her huſband, as herſelf,———appear-

and that is, the making the vegetation and growth of trees and plants, the very means of the building of their little nests and cells [d], such as are the galls and balls found on the leaves and

'ed to be, by measure, a great deal above 300 yards, and yet weigh-'ed but two grains and an half.' Boyle Subtil. of Effluv. chap, 2.

[d] Since my penning this, I have met with the most sagacious Malpighi's account of galls, &c. and find his descriptions to be exceedingly accurate and true, having traced myself many of the productions he hath mentioned. But I find Italy and Sicily (his book de Gallis being published long after he was made professor at Messina) more luxuriant in such productions than England, at least than the parts about Upminister, where I live, are. For many, if not most of those about us, are taken notice of by him, and several others besides that I never met with; although I have, for many years, as critically observed all the excrescences, and other morbid tumours of vegetables, as is almost possible, and do believe that few of them have escaped me.

As to the method how those galls and balls are produced, the most simple, and consequently the most easy to be accounted for, is that in the gems of oak, which may be called squamous oak-cones, capitula squamata, in Malpighi whose description not exactly answering our English cones in divers respects, I shall therefore pass his by, and shew only what I have observed myself concerning them.

These cones are, in outward appearance, perfectly like the gems only vastly bigger; and indeed they are no other than the gems, increased in bigness, which naturally ought to be pushed out in length: the cause of which obstruction of the vegetation is this: into the very heart of the young tender gem or bud (which begins to be turgid in June, and to shoot towards the latter end of that month, or beginning of the next; into this, I say) the parent insect thrusts one and branches of divers vegetables, ſuch as the oak, the willow [e], the briar, and ſome others. Now

one or more eggs, and not perhaps without ſome venomous ichor therewith. This egg ſoon becomes a maggot, which eats itſelf a little cell in the very heart or pith of the gem, which is the rudiment of the branch, together with its leaves and fruit, as ſhall be hereafter ſhewn. The branch being thus wholly deſtroyed, or at leaſt its vegetation being obſtructed, the ſap that was to nouriſh it, is diverted to the remaining parts of the bud, which are only the ſcaly teguments; which by theſe means grow large and flouriſhing, and become a covering to the inſect-caſe, as before they were to the tender branch and its appendage.

The caſe lying within this cone, is at firſt but ſmall, as the maggot included in it is; but by degrees, as the maggot increaſeth, ſo it grows bigger, to about the ſize of a large white pea, long and round, reſembling the ſhape of a ſmall acorn.

The inſect itſelf is, according to the modern inſectologers, of the ichneumon-fly kind, with four membranaceous wings, reaching a little beyond the body, articulated horns, a large thorax, bigger than the belly; the belly ſhort and conical, much like the heart of animals; the legs partly whitiſh, partly black. The length of the body from head to tail, about two tenths of an inch; its colour, a very beautiful ſhining green, in ſome tending to a dark copper colour, Figures both of the cones, caſes, and inſects, may be ſeen among Malpighi's cuts of galls Tab. 13. and Tab. 20. Fig. 72. which Fig. 72. exhibits well enough ſome others of the gall-inſects, but its thorax is ſomewhat too ſhort for ours.

[e] Not only the willow, and ſome other trees, but plants alſo, as nettles, ground ivy, &c. have caſes produced on their leaves, by the injection of the eggs of an ichneumon-fly. I have obſerved thoſe caſes always to grow in, or adjoining to ſome rib of the leaf, and their production I conceive to be thus, viz. the parent inſect, with

Now, this is ſo peculiar an artifice, and ſo far out of the reach of any mortal underſtanding, wit, or power, that if we conſider the matter, with ſome of its circumſtances, we muſt needs perceive manifeſt deſign, and that there is the concurrence of ſome great and wiſe Being, that hath, from the beginning, taken care of, and provided for the animal's good: for which reaſon, as mean as the inſtance may ſeem, I might be excuſed, if I ſhould enlarge upon its particulars. But two or three hints ſhall ſuffice.

In the firſt place, it is certain, that the formation of thoſe caſes and balls quite exceeds the cunning of the animal itſelf; but it is the act partly of the vegetable, and partly of ſome virulency, (or what ſhall I call it?) in the juice, or egg, or both, repoſited on the vegetable by the parent-animal[f]. And as

with its ſtiff ſetaceous tail, terebrates the rib of the leaf, when tender and makes way for its egg into the very pith or heart thereof, and probably lays in therewith, ſome proper juice of its body, to pervert the regular vegetation of it. From this wound ariſes a ſmall excreſcence, which when the egg is hatched into a maggot, grows bigger and bigger, as the maggot increaſes, ſwelling on each ſide the leaf between the two membranes, and extending itſelf into the parenchymous part thereof, until it is grown as big as two grains of wheat. In this caſe lies a ſmall, white rough maggot, which turns to an aurelia, and afterwards to a very beautiful green, ſmall ichneumon-fly.

[f] What I ſuſpected myſelf, I find confirmed by Malpighi, who, in his exact and true deſcription of the fly bred in the oaken galls, ſaith,

as this virulency is various, according to the difference of its animal, so is the form and texture of the cases and balls excited thereby; some being hard shells [g], some tender balls [h], some scaly

saith, 'Non sat fuit naturæ tam miro artificio terebram seu limam 'condidisse; sed inflicto vulnere, vel excitato foramine infundendum 'exinde liquorem intra terebram condidit: quare fracta per transversam muscarum terebra frequentissime, vivente animali, guttæ 'aliquot diaphani humoris effluunt.' And a little after, he confirms by ocular observation, what he imagined before, viz. 'Semel 'prope Junii finem vidi muscam, qualem superius delineavi, insidentem quercinæ gemmæ, adhuc germinanti; hærebat etenim 'foliolo stabili ab apice hiantis gemmæ erumpenti: et convulso in 'arcum corpore, terebram evaginabat, ipsamque tensam immittebat; et tumefacto ventre circa terebræ radicem tumorem excitabat, 'musca interpolatis vicibus remittebat. In folio igitur, avulsa 'minima et diaphana reperi ejecta ova, simillima iis, quæ adhuc 'in tubis supererant. Non licuit iterum idem admirari spectaculum, &c.

Some what like this, which Malpighi saw, I had the good fortune to see myself once, some years ago: and that was the beautiful, shining oak-ball ichneumon strike its terebra into an oak-apple divers times, no doubt to lay its eggs therein. And hence I apprehend we see many vermicules towards the outside of many of the oak apples, which I guess were not what the primitive insects laid up in the gem, from which the oak-apple had its rise, but some other supervenient, additional insects, laid in after the apple was grown, and whilst it was tender and soft.

[g] The Aleppo-galls, wherewith we make ink, may be reckoned of this number, being hard, and no other than cases of insects which are bred in them; who, when come to maturity, gnaw their way out of them; which is the cause of those little holes observable in them. Of the insects bred in them, see Philos. Trans. No. 245.

 Of

Of this number alſo are thoſe little ſmooth caſes, as big as large pepper-corns, growing cloſe to the ribs under oaken leaves, globous, but flattiſh; at firſt touched with a bluſhing red, afterwards growing brown, hollow within, and an hard thin ſhell without. In this lieth commonly a rough, white maggot, which becomes a little long-winged, black ichneumon-fly, that eats a little hole in the ſide of the gall, and ſo gets out.

[h] For a ſample of the tender balls, I ſhall chuſe the globous ball, as round, and ſome as big as ſmall muſket-bullets, growing cloſe to the ribs, under oaken-leaves, of a greeniſh yellowiſh colour, with a bluſh of red; their ſkin ſmooth, with frequent riſings therein. Inwardly they are very ſoft and ſpungy; and in the very centre is a caſe with a white maggot therein, which becomes an ichneumon-fly, not much unlike the laſt. As to this gall, there is one thing I have obſerved ſomewhat peculiar, and I may ſay providential, and that is, that the fly lies all the winter in theſe balls in its infantine-ſtate, and comes not to its maturity till the following ſpring. In the autumn, and winter, theſe balls fall down with their leaves to the ground, and the inſect incloſed in them is there fenced againſt the winter froſts, partly by other leaves falling pretty thick upon them, and eſpecially by the thick parenchymous, ſpongy walls, afforded by the galls themſelves.

Another ſample ſhall be the large oak-balls, called oak-apples, growing in the place of the buds, whoſe generation, vegetation and figure, may be ſeen in Malpig. de Gallis, p. 24. and Tab. 10. fig. 33, &c. Out of theſe galls, he ſaith, various ſpecies of flies come, but he names only two, and they are the only two I ever ſaw come out of them: ‘ Frequenter, ſaith he, ſubnigræ ſunt muſcæ ‘ brevi munitæ terebra. Inter has aliquæ obſervantur aureæ, ‘ levi viridis tinctura ſuffuſæ, oblonga pollentes terebra.’ Theſe two differently coloured flies I take to be no other than male and female of the ſame ſpecies. I have not obſerved tails, which are their terebræ, in all, as Malpighi ſeems to intimate: perhaps they were hid in their thecæ, and I could not diſcover them: but I rather think there were none, and that thoſe were the males: but in others, I have obſerved long, recurvous tails, longer than their whole bodies; and theſe I take to be the females. And in the oak apples ſcaly [i], ſome ſmooth [k], ſome hairy [l], ſome long, ſome

apples themſelves, I have ſeen the aureliæ, ſome with, ſome without tails. And I muſt confeſs, it was not without admiration, as well as pleaſure, that I have ſeen with what exact neatneſs and artifice, the tail hath been wrapt about the aurelia, whereby it is ſecured from either annoying the inſect, or being hurt itſelf.

[i] See before, note [d], p. 98.

[k] Ibid.

[l] Of the rough or hairy excreſcences, thoſe on the briar, or dog-roſe, are a good inſtance. Theſe ſpongiolæ villoſæ, as Mr. Ray, gallæ ſtrumoſæ, as Dr. Malpighi calls them, are thus accounted for by the latter; 'Ex copioſis relictis ovis ita turbatur affluens (rubi) ſuccus, ut ſtrumoſa fiant complura tubercula ſimul confuſè congeſta, 'quæ utriculorum ſeribus, et fibrarum implicatione contexta, ra- 'moſas propagines germinant,' ita ut minima quaſi ſylva appareat. 'Quælibet propago ramos, hinc inde villoſos edit. Hinc inde pilæ 'pariter erumpunt,' &c.

Theſe balls are a ſafe repoſitory to the inſect all the winter in its vermicular-ſtate. For the eggs laid up, and hatched the ſummer before, do not come to mature inſects until the ſpring following, as Mr. Ray rightly obſerves in Cat. Cantab.

As to the inſects themſelves, they are manifeſtly ichneumon-flies, having four wings, their alvus thick and large towards the tail; and tapering up till it is ſmall and ſlender at its ſetting on to the thorax. But the alvi, or bellies, are not alike in all, though coloured alike. In ſome they are as is now deſcribed, and longer, without terebræ, or tails; in ſome ſhorter, with tails; and in ſome yet ſhorter, and thick, like the belly of the ant, or the heart of animals, as in thoſe before (note [d], p. 98.) But for a farther deſcription of them, I ſhall refer to Mr. Ray, Cat. Plant. circa Cantab. under Roſa ſylveſt.

ſome round, ſome conical, &c.[m]. And, in the laſt place, let us add, that thoſe ſpecies of inſects are all endued with peculiar and exactly made parts for this ſervice, to bore and pierce the vegetable, and to reach and inject their eggs and juice into the tender parts thereof.

[m] It being an inſtance ſomewhat out of the way, I ſhall pitch upon it for an example here, viz. the gouty ſwellings in the body, and the branches of the blackberry buſh; of which Malpighi hath given us two good cuts in Tab. 17. fig. 62. The cauſe of theſe is manifeſtly from the eggs of inſects laid in, whilſt the ſhoot is young and tender, as far as the pith, and in ſome places not ſo deep: which, for the reaſons before mentioned, makes the young ſhoots tumify, and grow knotty and gouty.

The inſect that comes from hence is of the former tribe, a ſmall ſhining, black ichneumon-fly, about a tenth of an inch long, with jointed, red, capillary horns, four long wings, reaching beyond the body, a large thorax, red legs, and a ſhort heart-like belly. They hop like fleas. The males are leſs than the females; are very venereous, endeavouring a coitus in the very box in which they are hatched: getting up on the females, and tickling and thumping them with their breeches and horns to excite them to venery.

THE

The Conclusion.

AND now, thefe things being curioufly confidered, what lefs can be concluded, than that there is manifeft defign and forecaft in this cafe, and that there muft needs be fome wife artift, fome careful, prudent confervator, that from the very beginning of the exiftence of this fpecies of animals, hath, with great dexterity and forecaft, provided for its prefervation and good! For what elfe could contrive and make fuch a fet of curious parts, exactly fitted up for that fpecial purpofe; and withal implant in the body fuch peculiar impregnations, as fhould have fuch a ftrange uncouth power on a quite different rank of creatures? And laftly, what fhould make the infect aware of this its ftrange faculty and power, and teach it fo cunningly and dexteroufly to employ it for its own fervice and good!

BOOK IX.

OF REPTILES, AND THE INHABITANTS OF THE WATERS.

CHAP. I.

OF REPTILES.

HAVING dispatched the insect-tribe, there is but one genus of the land-animals remaining to be surveyed, and that is, that of reptiles [a]. Which

[a] Notwithstanding I have before, in book iv. chap. 13. taken notice of the earth-worm; yet it being a good example of the Creator's wise and curious workmanship, in even this meanest branch of the creation, I shall superadd a few farther remarks from Drs. Willis and Tyson. Saith Willis, 'Lumbricus terrestris, 'licet vile et contemptibile habetur, organa vitalia, necnon et alia 'viscera et membra divino artificio admirabiliter fabrefacta sortitur: totius

Which I ſhall diſpatch in a little compaſs, by reaſon I have ſomewhat amply treated of others and many of the things may be applied here. But there are ſome things in which this tribe is ſomewhat ſingular, which I ſhall therefore take notice of briefly in this place. One is their motion, which I have in another place ° taken notice of to be not leſs curious, than it is different from that

'totius corporis compages muſculorum annularium catena eſt, 'quorum fibræ orbiculares contractæ quemque annulum, prius am-'plum, et dilatum, anguſtiorem et longiorem reddunt.' [This muſcle in earth-worms I find is ſpiral, as in a good meaſure is their motion likewiſe; 'ſo that by this means they can, like the worm 'of an augre, the better bore their paſſage into the earth. Their 'reptile motion alſo may be explained by a wire wound on a cy-'linder, which when ſlipped off, and one end extended and held 'faſt, will bring the other near it. So the earth-worm, having 'ſhot out, or extended its body, which is with a wreathing, it takes 'hold by thoſe ſmall feet it hath, and ſo contracts the hinder part 'of its body.' Thus the curious and learned Dr. Tyſon, Philoſ. Tranſ. No. 147.) 'Nam proinde cum corporis portio ſuperior elon-'gata, et exporrecta, ad ſpatium alterius extenditur, ibidemque 'plano affigitur, ad ipſum quaſi ad centrum portio corporis inferior 'relaxata, et abbreviata facile pertrahitur. Pedunculi ſerie qua-'druplici, per totam longitudinem lumbrici diſponuntur; his quaſi 'totidem uncis, partem modo hanc, modo iſtam, plano affigit, 'dum alteram exporrigit, aut poſt ſe ducit. Supra oris hiatum, 'proboſcide, qua terram perforat et elevat, donatur.' And then he goes on with the other parts that fall under view, the brain, the gullet, the heart, the ſpermatic veſſels, the ſtomachs and inteſtines, the foramina on the top of the back, adjoining to each ring, ſupplying the place of lungs, and other parts. Willis de Anim. Brut. p. 1. c. 3.

° See book iv. chap. 8.

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that of other animals, whether we confider the manner of it, as vermicular, or finuous [p], or like that of the fnail [q], or the caterpillar [r], or the multipedous

[p] There is a great deal of geometrical neatnefs and nicety, in the finuous motion of fnakes, and other ferpents. For the affifting in which action, the annular fcales under their body are very remarkable, lying crofs the belly, contrary to what thofe in the back, and the reft of the body do; alfo as the edges of the foremoft fcales lie over the edges of their following fcales, from head to tail; fo thofe edges run out a little beyond, or over their following fcales; fo as that when each fcale is drawn back, or fet a little upright, by its mufcle, the outer edge thereof, or foot it may be called, is raifed alfo a little from the body, to lay hold on the earth, and fo promote and facilitate the ferpent's motion. This is what may be eafily feen in the flough, or belly of the ferpent-kind. But there is another admirable piece of mechanifm, that my antipathy to thofe animals hath prevented my prying into; and that is, that every fcale hath a diftinct mufcle, one end of which is tacked to the middle of its fcale; the other, to the upper edge of its following fcale. This Dr. Tyfon found in the rattle-fnake, and I doubt not is in the whole tribe.

[q] The wife author of nature, having denied feet and claws to enable fnails to creep and climb, hath made them amends in a way more commodious for their ftate of life, by the broad fkin along each fide of the belly, and the undulating motion obfervable there. By this latter it is they creep; by the former, affifted with the glutinous flime emitted from the fnail's body, they adhere firmly and fecurely to all kinds of fuperficies, partly by the tenacity of their flime, and partly by the preffure of the atmofphere. Concerning this part, which he calls the fnail's feet, and their undulation, fee Dr. Lifter's Exercit. Anat. 1. fect. 1. and 37.

[r] The motive parts, and motion of caterpillars, are ufeful, not only to their progreffion and conveyance from place to place; but alfo

multipedous[s], or any other way; or the parts ministering to it, particularly the spine[t], and the muscles co-operating with the spine, in such as have bone, and the annular, and other muscles, in such as have none, all incomparably made for those curious, and, I may say, geometrical various

also to their more certain, easy, and commodious gathering of food: for having feet before and behind, they are not only enabled to go by a kind of steps made by their fore and hind-parts; but also to climb up vegetables, and to reach from their boughs and stalks for food at a distance: for which services their feet are very nicely made both before and behind. Behind, they have broad palms for sticking to, and these beset almost round with small sharp nails, to hold and grasp what they are upon: before, their feet are sharp and hooked, to draw leaves, &c. to them, and to hold the fore-part of the body, whilst the hinder-parts are brought up thereto. But nothing is more remarkable in these reptiles, than that these parts and motions are only temporary, and incomparably adapted only to their present nympha-state; whereas in their aurelia-state, they have neither feet nor motion, only a little in their hinder-parts: and in the mature state, they have the parts and motion of a flying insect, made for flight.

[s] It is a wonderful pretty mechanism, observable in the going of multipedes, as the juli, and scolopendræ, that on each side the body, every leg hath its motion, one very regularly following the other from one end of the body to the other, in a way not easy to be described in words; so that their legs in going, make a kind of undulation, and give the body a swifter progression than one would imagine it should have, where so many feet are to take so many short steps.

[t] 'Vertebrarum apophyses breviores sunt, præcipue juxta caput 'cujus propterea flexus in aversum, et latera, facilis viperis est; secus

various windings and turnings, undulations, and all the various motions to be met with in the reptile kind.

ANOTHER thing that will deserve our notice, is, the poison [u] that many of this tribe are stocked with. Which I the rather mention, because some make it an objection against the divine superintendence and providence, as being a thing so far from useful, they think, that it is rather mischievous

'secus leonibus, &c. Incumbit his ossibus ingens musculorum minutorum præsidium, tum spinas tendinum exilium magno apparatu deducentium, tum vertebras potissimum in diversa flectentium, atque erigentium. Adeoque illam corporis miram agilitatem, non tantum, (ut Aristot.) ὅτι εὐκαμπεῖς καὶ χονδρώδεις οἱ σπόνδυλοι, quoniam faciles ad flexum, et cartilagineas produxit vertebras, sed quia etiam multiplicia motus localis instrumenta musculos fabrefecit provida rerum parens natura, consecuta fuit.' Blas. Anat. Anim. p. 1. c. 39. de Vipera e Veslingio.

'That which is more remarkable in the vertebræ (of the rattle-snake, besides the other curious articulations,) is, that the round ball in the lower part of the upper vertebra, enters a socket of the upper part of the lower vertebra, like as the head of the os femoris doth the acetabulum of the os ischii; by which contrivance, as also the articulation with one another, they have that free motion of winding their bodies any way.' Dr. Tyson's Anat of the Rattle-snake in Philosoph. Transf. No. 144. What is here observed of the vertebræ of this snake, is common to this whole genus of reptiles.

[u] My ingenious and learned friend, Dr. Mead, examined with his microscope, the texture of a viper's poison, and found therein at

chievous and destructive of God's creatures. But the answer is easy, that as to man those creatures are not without their great uses, particularly in the cure of some [w] of the most stubborn diseases; however,

at first only 'a parcel of small salts nimbly floating on the liquor; 'but in a short time the appearance was changed, and these saline 'particles were shot out into crystals, of an incredible tenuity and 'sharpness, with something like knots here and there, from which 'they seemed to proceed; so that the whole texture did in a man-'ner represent a spider's web, though infinitely finer.' Mead of Poisons, p. 9.

As to the nature and operation of this poison, see the same ingenious author's hypothesis, in his following pages.

This poison of the viper lieth in a bag in the gums, at the upper end of the teeth. It is separated from the blood by a conglomerated gland, lying in the anterior lateral part of the os sincipitis, just behind the orbit of the eye: from which gland lieth a duct, that conveys the poison to the bags at the teeth.

The teeth are tubulated, for the conveyance, or emission of the poison into the wound the teeth make; but their hollowness doth not reach to the apex, or top of the tooth, (that being solid and sharp, the better to pierce;) but it ends in a long slit below the point, out of which the poison is emitted. These perforations of the teeth, Galen saith, the mountebanks used to stop with some kind of paste, before they suffered the vipers to bite them before their spectators. Cuts of these parts, &c. may be seen in the last cited book of Dr. Mead. Also Dr. Tyson's Anat. of the Rattle-Snake, in Phil. Transf. No. 144.

[w] That vipers have their great uses in physic is manifest from their bearing a great share in some of our best antidotes, such as theriaca Andromachi, and others; also in the cure of the elephantiasis, and other the like stubborn maladies, for which I shall refer to the medical

however, if they were not, there would be no in-

dical writers. But there is so singular a case in the curious collection of Dr. Ol. Wormius, related from Kircher, that I shall entertain the reader with it. Near the village of Saffa, about eight miles from the city Bracciano in Italy, saith he, 'Specus seu caverna, 'vulgo La Grotta del Serpi, duorum hominum capax, fistulosis 'quibusdam foraminibus in formam cribri perforata cernitur, ex 'quibus ingens quædam, principio veris, diversiculorum serpentum, nulla tamen, ut dicitur, singulari veneni qualitate imbutorum progenies quotannis pullulare solet. In hac spelunca elephantiacos, leprosos, paralyticos, arthriticos, podagricos, &c. 'nudos exponere solent, qui mox halituum subterraneorum calore 'in sudorem resoluti, serpentum propullantium, totum corpus infirmi implicantium, suctu linctuque ita omni vitioso virulentoque 'humore privare dicuntur, ut repetito hoc per aliquod tempus medicamento, tandem perfectæ sanitati restituantur.' This cave Kircher visited himself, found it warm, and every way agreeable to the description he had of it; he saw their holes, heard a murmuring hissing noise in them; but although he missed seeing the serpents, it being the season for their creeping out, yet he saw great numbers of their exuviæ, or sloughs, and an elm growing hard by laden with them.

The discovery of this cave was by the cure of a leper going from Rome to some baths near this place; who losing his way, and being benighted, happened upon this cave; and finding it very warm, pulled off his clothes, and being weary and sleepy, had the good fortune not to feel the serpents about him till they had wrought his cure. Vide Museum Worm. l. 3. c. 9.

The before commended Dr. Mead thinks our physicians deal too cautiously and sparingly, in their prescribing only small quantities of viper's flesh, &c. in the elephantiasis, and stubborn leprosies: but he recommended rather the jelly or broth of vipers; or, as the ancient manner was, to boil vipers and eat them like fish; or at least to drink wine, in which they have been long infused. Vide Mead, ubi supra, p. 34.

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juſtice for God to make a ſet of ſuch noxious creatures, as rods and ſcourges, to execute the divine chaſtiſements upon ungrateful and ſinful men. And I am apt to think that the nations which know not God, are the moſt annoyed with thoſe noxious reptiles, and other pernicious creatures. As to the animals themſelves, their poiſon is, no doubt, of ſome great and ſpecial uſe to themſelves, ſerving to the more eaſy conqueſt, and ſure capture of their prey, which might otherwiſe be too reſty and ſtrong, and if once eſcaped, would hardly be again recovered, by reaſon of their ſwifter motion, and the help of their legs; beſides all which, this their poiſon may probably be of very great uſe to the digeſtion of their food.

And as to the innocuous part of the reptile-kind, they as well deſerve our notice for their harmleſneſs, as the others did for their poiſon. For as thoſe are endowed with poiſon, becauſe they are predacious; ſo theſe need it not, becauſe their food is near at hand, and may be obtained without ſtrife and conteſt, the next earth [x] afford-

[x] That earth-worms live upon earth, is manifeſt from the little curled heaps of their dung ejected out of their holes. But in Phil. Tranſ. No. 241. I have ſaid, it is in all probability earth made of rotted roots and plants, and ſuch like nutritive things, not pure earth. And there is farther reaſon for it, becauſe worms will drag the leaves of trees into their holes.

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ing food to ſuch as can terebrate, and make way into it by their vermicular faculty; and the next vegetable being food to others that can climb and reach [y], or but crawl to it.

[y] Snails might be in danger of wanting food, if they were to live only upon ſuch tender plants as are near the ground, within their reach only; to impower them therefore to extend their purſuits farther, they are enabled, by the means mentioned in note q. p. 108. to ſtick unto, and creep up walls and vegetables at their pleaſure.

CHAP.

CHAP. II.

OF THE INHABITANTS OF THE WATERS

I HAVE now gone through that part of the animal world, which I propofed to furvey, the animals inhabiting the land.

As to the other part of the terraqueous globe, the waters, and the inhabitants thereof, not having time to finifh what I have begun on that large fubject, I fhall be forced to quit it for the prefent, although we have there as ample and glorious a fcene of the infinite Creator's power and art, as hath been already fet forth on the dry land. For the waters themfelves are an admirable work of God [z], and of infinite ufe [a] to that part of the globe already

[z] Befides their abfolute neceffity and great ufe to the world, there are feveral topics, from whence the waters may be demonftrated to be God's work; as the creating fo vaft a part of our globe; the placing it commodioufly therein, and giving it bounds; the methods

already ſurveyed; and the prodigious variety [b], and multitudes of curious and wonderful things obſervable in its inhabitants of all ſorts, are an inexhauſtible ſcene of the Creator's wiſdom and power. The vaſt bulk of ſome [c], and prodigious minuteneſs of others [d], together with the incom-

thods of keeping it ſweet and clean, by its ſaltneſs, by the tides, and agitations by the winds; the making the waters uſeful to the vegetation of plants, and for food to animals, by the noble methods of ſweetning them; and many other things beſides, which are inſiſted on in that part of my ſurvey.

[a] Pliny having named divers mirabilia aquarum, to ſhew their power; then proceeds to their uſes, viz. 'Eædem cadentes omnium 'terra naſcentium cauſa fiunt, prorſus mirabili natura, ſiquis velit 'reputare, ut fruges gignantur, arbores fruticeſque vivant, in cœ-'lum migrare aquas, animamque etiam herbis vitalem inde deferre, 'juſta confeſſione, omnes terræ quoque vires aquarum eſſe beneficio. 'Quapropter ante omnia ipſarum potentiæ exempla ponemus: 'cunctas enim quis mortalium enumerare queat?' And then he goes on with an enumeration of ſome waters famed for being medicinal, or ſome other unuſual quality. Plin. l. 31. c. 1, and 2.

[b] Pliny reckons 176 kinds in the waters, whoſe names may be met with in his l. 32. c. 11. but he is ſhort in his account.

[c] Pliny, l. 9. c. 3. ſaith, that in the Indian ſea there are balenæ 'quaternum jugerum, (i. e. 960 feet) priſtes 200 cubitorum, (i. e. '300 feet).' And l. 32. c. 1. he mentions whales 600 feet long, and 360 broad, that came into a river of Arabia. If the reader hath a mind he may ſee his reaſon why the largeſt animals are bred in the ſea, l. 9. c. 2.

[d] As the largeſt, ſo the moſt minute animals are bred in the waters, as thoſe in pepper-water; and ſuch as make the green ſcum on

comparable contrivance and ſtructure of the bodies of all [e], the proviſions and ſupplies of food afforded to ſuch an innumerable company of eaters, and that in an element, unlikely, one would think, to afford any great ſtore of ſupplies [f]; the buſineſs of reſpiration performed in a way ſo different from, but equivalent to what is in land animals [g]; the adjuſtment of the organs of

on the waters, or make them ſeem as if green, and many others. See book iv. chap. 12.

[e] It might be here ſhewn, that the bodies of all the ſeveral inhabitants of the waters, are the beſt contrived and ſuited to that place and buſineſs in the waters, which is proper for them; that particularly, their bodies are clothed and guarded, in the beſt manner, with ſcales, or ſhells, &c. ſuitable to the place they are to reſide in, the dangers they may be there expoſed unto, and the motion and buſineſs they are there to perform: that the centre of gravity, of great conſideration in that fluid element, is always placed in the fitteſt part of the body: that the ſhape of their bodies, eſpecially the more ſwift, is the moſt commodious for making way through the waters, and moſt agreeable to geometrical rules; and many other matters beſides would deſerve a place here, were they not too long for notes, and that I ſhall anticipate what ſhall be more proper for another place, and more accurately treated of there.

[f] See before, book iv. chap. 11.

[g] Galen was aware of the reſpiration of fiſhes by their branchiæ. For having ſaid, that fiſhes have no occaſion of a voice, neither reſpire through the mouth, as land animals do, he ſaith, 'Sed earum, 'quas branchias nuncupamus, conſtructio, ipſis vice pulmonis eſt. 'Cum enim crebris ac tenuibus foraminibus ſint branchiæ hæc in'terceptæ, aeri quidem et vapori perviis, ſubtilioribus tamen quam

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of vision [h] to that element in which the animal liveth; the poise [i], the support [k], the motion of the body [l], forwards with great swiftness, and upwards

'pro mole aquæ; hanc quidem extra repellunt, illa autem prompte 'intromittunt.' Galen de usu Part. l. 6. c. 9. So also Pliny held, that fishes respired by their gills; but he saith Aristotle was of a different opinion. Plin. l. 9. c. 7. And so Aristotle seems to be in his History of Animals, l. 8. c. 2. and in other places. And I may add our famous Dr. Needham. See his De Form. Fœt. cap. 6. and Answer to Severinus.

[h] A protuberant eye would have been inconvenient for fishes, by hindering their motion in so dense a medium as water is; or else their brushing through so thick a medium would have been apt to wear, and prejudice their eyes; therefore their cornea is flat. To make amends for which, as also for the refraction of water, different from that of the air, the wise Contriver of the eye hath made the chrystalline spherical in fishes, which in animals, living in the air, is lenticular, and more flat.

[i] As I have shewed before, that the bodies of birds are nicely poised to swim in the air, so are those of fishes for the water, every part of the body being duly balanced, and the centre of gravity, as I said in note e, p. 117. accurately fixed And to prevent vacillation, some of the fins serve, particularly those of the belly; as Borelli proved, by cutting off the belly-fins, which cause the fish to reel to the right and left hand, and rendered it unable to stand steadily in an upright posture.

[k] To enable the fish to abide at the top, or bottom, or any other part of the waters, the air-bladder is given to most fishes, which, as it is more full or empty, makes the body more or less buoyant.

[l] The tail is the grand instrument of the motion of the body; not the fins, as some imagine. For which reason, fishes are more musculous and strong in that part, than in all the rest of their body, according

upwards and downwards with great readineſs and agility, and all without feet and hands, and ten thouſand things beſides; all theſe things, I ſay, do lay before us ſo various, ſo glorious, and withal ſo inexhauſtible a ſcene of the divine power, wiſdom, and goodneſs, that it would be in vain to engage myſelf in ſo large a province, without allotting as much time and pains to it, as the preceding ſurvey hath coſt me. Paſſing by therefore that part of our globe, I ſhall only ſay ſomewhat very briefly concerning the inſenſitive creatures, particularly thoſe of the vegetable kingdom, and ſo conclude this ſurvey.

cording as it is in the motive parts of all animals, in the pectoral muſcles of birds, the thighs of man, &c.

If the reader hath a mind to ſee the admirable method, how fiſhes row themſelves by their tail, and other curioſities relating to their ſwimming; I ſhall refer him to Borelli de Mot. Animal par. 1. cap. 23. particularly to prop. 213.

BOOK X.

OF VEGETABLES.

THE vegetable kingdom, although an inferior branch of the creation, exhibits to us fuch an ample fcene of the Creator's contrivance, curiofity, and art, that I much rather chufe to fhew what might be faid, than engage too far in particulars. I might infift upon the great variety there is, both of trees and plants provided for all ages, and for every ufe and occafion of the world[m]; fome for building, for tools and utenfils of every kind; fome hard, fome foft; fome tough and ftrong, fome brittle; fome long and tall, fome fhort and low; fome thick and large,

[m] The fifth book of Theophraftus's Hiftory of Plants may be here confulted; where he gives ample inftances of the various conftitutions and ufes of trees, in various works, &c. See alfo before, book iv. chap. 13.

some small and slender; some for physic [n], some for food, some for pleasure; yea, the most abject shrubs [o], and the very bushes and brambles themselves, the husbandman can testify the use of.

I might

[n] 'Invisis quoque herbis inseruit [natura] remedia: quippe cum 'medicinas dederit etiam aculeatis—in quibus ipsis providentiam 'naturæ satis admirari amplectique non est.—Inde excogitavit aliquas 'aspectu hispidas, tactu truces, ut tantum non vocem ipsius fingentis 'illas, rationemque reddentis exaudire videamur, ne se depascat avida 'quadrupes, ne procaces manus rapiant, ne neglecta vestigia obterant, 'ne insidens ales infringat: his muniendo aculeis, telisque armando, 'remediis ut tuta ac salva sint. Ita hoc quoque quod in iis odimus, 'hominum causa excogitatum.' Plin. Nat. Hist. l. 22. c. 6.

'Are some of the species of nature noxious? They are also use-'ful.—Doth a nettle sting? It is to secure so good a medicine from 'the rapes of children and cattle. Doth the bramble cumber a gar-'den? it makes the better hedge; where if it chanceth to prick the 'owner, it will tear the thief,' Grew's Cosmolog. lib. 3. cap. 2. sect. 47.

[o] That the most abject vegetables, &c. have their use, and are beneficial to the world, may, in some measure, appear from the use the northern people put rotten wood, &c. unto. 'Satis ingeniosum 'modum habent populi septentrionales in nemoribus nocturno tem-'pore pertranseuntes, imo et diurno, quando in remotioribus aqui-'lonis partibus ante et post solstitium hyemale continuæ noctes ha-'bentur. Quique his remediis indigent, cortices quercinos inquir-'unt putres, eosque collocant certo interstitio itineris instituti, ut 'eorum splendore, quo voluerint, perficiant iter. Nec solum hoc 'præstat cortex, sed et truncus putrefactus, ac fungus ipse agaricus 'appellatus,' &c. Ol. Mag. Hist. l. 2. c. 16.

To this we may add thistles in making glass, whose ashes, Dr. Merret saith, are the best, viz. the ashes of the common way thistle,

though

I might alſo ſurvey here the curious anatomy and ſtructure of their bodies [p], and ſhew the admirable proviſion made for the conveyance of the lymphatic and eſſential juices, for communicating the air, as neceſſary to vegetable, as animal life [q]: I might alſo ſpeak of, even the very

though all thiſtles ſerve to this purpoſe. Next to thiſtles are hop-ſtrings, cut after the flowers are gathered. Plants that are thorny and prickly, ſeem to afford the beſt and moſt ſalt. Merret's Obſervations on Anton. Ner. p. 265.

> Quid majora ſequar? Salices humileſque geniſtæ,
> Aut illæ pecori frondem, aut paſtoribus umbram
> Sufficiunt, ſepemque ſatis, et pabula melli.
>
> Virg. Georg. I. 2, ver. 434.

[p] Dr. Beal, who was very curions, and tried many experiments upon vegetables, gives ſome good reaſons to imagine, that there is a direct communication between the parts of the tree and the fruit, ſo that the ſame fibres which conſtitute the root, trunk, and boughs, are extended into the very fruit. And in old horpbeans, I have obſerved ſomething very like this: in many of which, there are divers great and ſmall ribs, almoſt like ivy, only united to the body, running from the root up along the outſide of the body, and terminating in one ſingle, or a few boughs: which bough or boughs ſpread again into branches, leaves, and fruit. See what Dr. Beal hath in Lowth. Abridgm. vol. 2. p. 710.

But as to the particular canals, and other parts relating to the anatomy of vegetables, it is too long a ſubject for this place, and therefore I ſhall refer to Seign. Malpighi's and Dr Grew's labours in this kind.

[q] 'Tanta eſt reſpirationis neceſſitas, et uſus, ut natura in ſingulis 'viventium ordinibus varia, ſed analoga, paraverit inſtrumenta, 'quæ

very covering they are provided with, becaufe it is a curious work in reality, although lefs fo in appearance; and much more therefore might I furvey the neat variety and texture of their leaves[r], the admirable finery, gaiety, and fragrancy of their

'quæ pulmones vocamus [and fo he goes on with obferving the 'apparatus made in the various genera of animals, and then faith,] 'In plantis vero, quæ infimum animalium attingunt ordinem, tan'tam trachearum copiam et productionem extare par eft, ut his 'minimæ vegetantium partes præter corticem irrigentur.—Plantæ 'igitur, ut conjectari fas eft, cum fint viventia, vifceribus infixa 'terræ, ab hac, feu potius ab aqua et aere commixtis et percolatis a 'terra, refpirationis fuæ materiam recipiunt, ipfarumque tracheæ ab 'halitu terræ, extremas radices fubingreffo, replentur.' Malpig. Op. Anat. Plant. p. 15.

Thefe tracheæ, or air-veffels, are vifible, and appear very pretty in the leaf of fcabious, or the vine, by pulling afunder fome of its principal ribs, or great fibres; between which, may be feen the fpiral air-veffels, like threads of cobweb a little uncoiled; a figure whereof, Dr. Grew hath given us in his Anat. Plant. fig. 51, 52.

As to the curious coiling, and other things relating to the ftructure of thofe air-veffels, I refer to Malpighi, p. 14. and Dr. Grew, ib. l. 3. c. 3. fect. 16, &c. and l. 4. c 4. fect. 19. of Mr. Ray, from them fuccinctly. Hift. Plant. l. 1. c. 4.

[r] Concerning the leaves, I fhall note only two or three things: 1. As to the fibres of the leaf, they ftand not in the ftalk, in an even line, but always in an angular, or circular pofture, and their vafcular fibres or threads are 3, 5, or 7. The reafon of their pofition thus, is for the more erect growth and greater ftrength of the leaf, as alfo for the fecurity of its fap. Of all which, fee Dr. Grew, l. 1. c. 4. fect. 8, &c. and l. 4. par. 1. c. 3. alfo tab. 4. fig. 2, to 11. Another obfervable in the fibres of the leaf, is their orderly pofition

their flowers[s], I might alſo inquire into the won-
derful

tion, ſo as to take in an eighth part of a circle, as in mallows; in ſome a tenth, but in moſt a twelfth, as in holy-oak; or a ſixth, as in ſyringo. Id. ib. tab. 46, 47.

2. The art in folding up the leaves before the eruption of their gems, &c. is incomparable, both for its elegancy and ſecurity, viz. 'In taking up, ſo as their forms will bear, the leaſt room; and in 'being ſo conveniently couched as to be capable of receiving pro-'tection from other parts, or of giving it to one another, e. g. firſt, 'there is the bow-lap, where the leaves are all laid ſomewhat con-'vexly one over another, but not plaited—but where the leaves 'are not ſo thick ſet, as to ſtand in the bow-lap, there we have the 'plicature, or the flat-lap; as in roſe-trees, &c. And ſo that curious obſerver goes on ſhewing the various foldings, to which he gives the names of the duplicature, multiplicature, the fore-rowl, back-rowl, and tre-rowl, or treble-rowl, Grew. ib. l. 1. c. 4. ſect. 14, &c. To theſe he adds ſome others, l. 4. p. 1. c. 1. ſect. 9. Conſult alſo Malpig. de Gemmis, p. 22. &c.

To theſe curious foldings, we may add another noble guard by the interpoſition of films, &c. of which Dr. Grew ſaith, there are about ſix ways, viz. leaves, furfoils, interfoils, ſtalk, hoods, and mantlings. Grew, ib. and tab. 41, 42. Malpig. ib.

[s] In the flower may be conſidered the empalement, as Dr. Grew, the calix, or perianthium, as Mr. Ray and others, call it, deſigned to be a ſecurity, and bands to the other parts of the flower. 'Floris 'velut baſis et fulcimentum eſt.' Ray Hiſt. l. 1. c. 10. Flowers, whoſe petala are ſtrong, as tulips, have no calix. Carnations, whoſe petala are long and ſlender, have an empalement of one piece: and others, ſuch as the knap-weeds, have it conſiſting of ſeveral pieces, and in divers rounds, and all with a counter-changeable reſpect to each other, for the greater ſtrength and ſecurity of themſelves, and the petala, &c. they include

derful generation and make of the feed [t], and the great ufefulnefs of their fruit: I might fhew that the rudiments and lineaments of the parent-vegetable, though never fo large and fpacious, is locked up in the little compafs of their fruit or feed, though fome of thefe feeds are fcarce vifible to the naked eye [u]. And forafmuch as the perpetuity

The next is the foliation, as Dr. Grew, the petala, or folia, as Mr. Ray, and others. In thefe, not only the admirable beauty, and luxuriant colours are obfervable, but alfo their curious foldings in the calix, before their expanfion. Of which Dr. Grew hath thefe varieties, viz. the clofe-couch, as in rofes; the concave-couch, as in blattaria flore albo; the fingle-plait, as in peafe bloffoms; the double-plait, as in blue-bottles, &c. the couch and plait together, as in marigolds, &c. the rowl, as in ladies-bower: the fpire, as in mallows; and laftly, the plait and fpire together, as in convolvulus doronici folio. Lib. 1. cap. 5. fect. 6. and tab. 54.

As to the ftamina with their apices, and the ftylus, called the attire, by Dr. Grew, they are admirable, whether we confider their colours, or make, efpecially their ufe, if it be as Dr. Grew, Mr. Ray, and others imagine, namely, as a male fperm, to impregnate and fructify the feed. Which opinion is corroborated by the ingenious obfervations of Mr. Samuel Moreland, in Phil. Tranf. No. 287.

'Reliqua ufus alimentique gratia genuit (natura) ideoque fecula annofque tribuit iis. Flores vero odorefque in diem gignit: 'magna, ut palam eft, admonitione hominum, quæ fpectatiffime 'floreant, celerrime marcefcere.' Plin. Nat. Hift. l. 21. c. 1.

[t] As to the curious and gradual procefs of nature in the formation of the feed or fruit of vegetables, cuts being neceffary, I fhall refer to Dr. Grew, p. 45, and 209, and Malpig. p. 57.

[u] 'Vetus eft Empedoclis dogma, plantarum femina ova effe, ab 'iifdem decidua—Ineft in eo (ovo vel femine) velut in cicatrice, 'non

'non sola viventis carina, sed cum minimo trunco assurgentes 'partes, gemma scilicet, et insignes radicis cannas,' &c. Malp. ib. p. 81. Vide plura in tract. de Sem. veg. p. 14. et passim.

In Malpighi's life, a debate may be seen between him and Seig. Triumphetti, the provost of the garden at Rome, whether the whole plant be actually in the seed. The affirmative is maintained by Malpighi, with cogent arguments; among which, this is one: 'Non præoccupata mente, oculis microscopio armatis, lustret quæ- 'so phaseolorum seminalem plantulam nondum satam, in qua folia 'stabilia, hæcque ampla evidenter observabit; in eadem pariter 'gemmam, nodos, seu implantationes varias foliorum caulis de- 'prehendet. Caulem insignem fibris ligneis, et utriculorum seriebus 'constantem conspicue attinget.' And whereas Seig. Trumphetti had objected, that 'Vegetatione, metamorphosi, inedia plantas in 'alias degenerare, ut exemplo plurium (constat) præcipue tritici 'in lolium, et lolii in triticum versi.' In answer to this, which is one of the strongest arguments against Malpighi's assertion, Malpighi replies, 'Nondum certum est de integritate, et successu ex- 'perimenti, nam facienti mihi, et amicis, tritici metamorphosis non 'cessit. Admissa tamen metamorphosi, quoniam hœc neglecta cul- 'tura, aut vitio soli, aut aeris contingit—ideo ex morboso et mon- 'struoso affectu non licet inferre permanentem statum a natura in- 'tentum. Observo plantas sylvestres cultura varias reddi,' &c. I have more largely taken notice of Malpighi's answer, because he herein shews his opinion about the transmutation of vegetables. Vide Malpig. Vit. p. 67.

So Mr. Lewenhoeck, after his nice observations of an orange-kernel, which he made to germinate in his pocket, &c. concludes, 'Thus we see, how small a particle, no bigger than a coarse sand, '(as the plant is represented,) is increased, &c. A plain demon- 'stration, that the plant, and all belonging to it, was actually in 'the seed, in the young plant, its body, root,' &c. Philos. Trans. No. 287. See also Raii Cat. Cant. in Acer maj. from Dr. Highmore. But in all the seeds which I have viewed, except the maple, the plant appears the plainest to the naked eye, and also very elegant, in the nux vomica.

'Natura

petuity and safety of the species depends upon the safety of the seed and fruit in a great measure, I might therefore take notice of the peculiar care the great God of nature hath taken for the confer-

'Natura non observat magnitudinis proportionem inter semina 'et plantas ab iisdem ortas, ita ut majus semen majorem semper 'producat plantam, minus minorem. Sunt enim in genere her-'barum non pauca, quarum semina arborum nonnullarum semini-'bus non dico æqualia sunt, sed multo majora. Sic v. g. semina 'fabæ, &c. semina ulmi, &c. multis vicibus magnitudine superant.' Raii, ubi supra, l. 1. c. 13.

'Filicem reliquasque capillares herbas semine carere veteres 'plerique——prodidere; quos etiam secuti sunt e recentioribus 'nonnulli, Dodonæus, &c.—Alii e contra, Bauhinus, &c. Fili-'ces et congeneres spermatophoras esse contendunt; partim quia 'historia creationis,' Gen. ii. 12. &c.——hanc sententiam verissi-'mam esse—autopsia convincit.' Fredericus Cæsius, he saith, was the first that discovered these seeds with the help of a microscope. And since him, Mr. W. C. hath more critically observed them. Among other things observed by that ingenious gentleman, are these, 'Pixidulæ seu capsulæ semina continentes in plerisque hoc 'genus plantis perquam exili granulo arenæ vulgaris cinereæ plus 'duplo minores sunt; imo in nonnullis speciebus vix tertiam quar-'tamve arenulæ partem magnitudine æquant, vesicularum quarun-'dam annulis aut fasciolis vermiformibus obvolutarum speciem 'exhibentes. Nonnullæ ex his vesiculis 100 circiter semina con-'tinere deprehendebantur—adeo eximia parvitate ut nudo oculo 'prorsus essent invisibilia, nec nisi microscopii interventu detegi 'possent.—Osmunda regalis, quæ aliis omnibus filicis speciebus 'mole—antecellit—vascula seminalia obtinet æquæ cum reliquis 'congeneribus magnitudinis—quorum immensa et visum fugiens 'parvitas cum magnitudine plantæ collata—adeo nullam gerere 'proportionem invenietur, ut tantam plantam e tantillo semine pro-'duci attentum observatorem merito in admirationem rapiat.' Ray, ibid. l. 3. p. 132. This W. C. was Mr. Wil. Cole, as he owneth in a letter I have now in my hands of his to Mr. Ray, Oct. 1684.

ſervation and ſafety hereof[v]: as particularly in ſuch as dare to ſhew their heads all the year; how ſecurely their flower, ſeed, or fruit is locked up all the winter, together with their leaves and branches, in their gems[w]; and well fenced and covered there with neat and cloſe tunics. And for ſuch as dare not ſo to expoſe themſelves, with what ſafety they are perſerved under the coverture of the earth, in their root[x], ſeed[y], or fruit, till invited

[w] 'Vegetantium genus, ut debitam magnitudinem ſortiatur, et 'ſuæ mortalitatis jacturam ſucceſſiva prolis eductione reparet, ſtatis temporibus novas promit partes, ut tandem emergentes uteri, re-'centes edant ſoboles. Emanantes igitur a caule, caudice, ramis, 'et radicibus novellæ hujuſmodi partes, non illico laxatæ exten-'duntur, ſed compendio quodam coagmentatæ intra folii axillam 'cubantes, non parum ſubſiſtunt, gemmæ appellantur,' &c. And then that great man goes on to ſhew the admirable various methods of nature, in repoſiting, in that little compaſs, ſo large a part of a tree or plant, the curious ſtructure of the gems, the admirable guard afforded them, and the leaves, flowers, and ſeed contained in them, &c. Of which having taken notice before, I paſs over it now, and only refer to our author Malpighi, and Dr. Grew, in the places cited in note q, p. 122, and note s, p. 224.

[x] Of bulbous, and a great many more, probably of the far greater number of perennial roots of herbs, as arum, rape, crowfoot, &c. it is very obſervable, that their root is annually renewed, or repaired out of the trunk or ſtalk of itſelf; that is to ſay, the baſis of the ſtalk continually and by inſenſible degrees deſcending below the ſurface of the earth, and hiding itſelf therein, is thus both in nature, place, and office, changed into a true root. So in brownwort, the baſis of the ſtalk ſinking down by degrees, till it lies under ground, becomes the upper part of the root: and continuing ſtill to ſink, the next year becomes the lower part: and the next after that,

vited out by the kindly warmth of the ſpring! And when the whole vegetable race is thus called out, it is very pretty to obſerve the methods of nature in guarding thoſe inſenſitive creatures againſt harms and inconveniences, by making ſome, for inſtance, to lie down proſtrate, and others to cloſe themſelves up [z] upon the touch of animals, and the moſt to ſhut up their flowers,

that rots away; a new addition being ſtill yearly made out of the ſtalk, as the elder parts yearly rot away. Grew. ib. l. 2. p. 59. ubi plura vid.

[y] How ſafe and agreeable a conſervatory the earth is to vegetables, more than any other, is manifeſt from their rotting, drying, or being rendered infecund in the waters, or the air; but in the earth their vigour is long preſerved. Thus of ſeeds, particularly, Mr. Ray thinks, ſome may probably retain their fecundity for ten years, and others loſe it in five; but, ſaith he, 'In terræ gremio latitantia, 'quamvis tot caloris, frigoris, humoris et ſiccitatis varietatibus ibi-'dem obnoxia, diutius tamen, ut puto fertilitatem ſuam tuentur 'quam ab hominibus diligentiſſime cuſtodita; nam et ego et alii ante 'me multi obſervarunt ſinapeos vim magnam enatam in aggeribus 'foſſarum recens factis inque areis gramineis effoſſis, ubi poſt hom-'inum memoriam nulla unquam ſinapeos ſeges ſuccreverent. Quam 'tamen non ſponte ortam ſuſpicor, ſede ſeminibus in terra per tot, 'annos reſiduis etiam prolificis.' Ray. Hiſt. Pl. l. 1. c. 13.

[z] 'Plantæ nonnullæ æſchynomenæ veteribus dictæ, recentioribus 'vivæ, et ſenſitivæ, et mimoſæ, haud obſcura ſenſus indicia pro-'dunt; ſiquidem folia earum manu aut baculo tacta, et paululum 'compreſſa, pleno etiam meridie, ſplendente ſole, illico ſe contra-'hunt; in nonnullis etiam ſpeciebus cauliculi teneriores concidunt 'et velut marceſcunt; quod idem ab aere frigidiore admiſſo patiun-'tur.' Ray, Hiſt. Pl. T. 1. l. 18. App. ſect. 2. c. 2 p. 978.

their down [a]; or other their like guard, upon the close and cool of the evening, by means of rain, or other matters that may be prejudicial to the tender seed.

And now to these considerations relating to the seed, I might add the various ways of nature in dissipating and sowing it, some being, for this end, winged with light down, or wings, to be conveyed about by the winds; others being laid in elastic, springy cases, that when they burst and crack, dart their seed at convenient distances, performing thereby the part of a good husbandman [b]; others

[a] I have observed that many, if not most vegetables, do expand their flowers, down, &c. in warm, sun-shiny weather, and again close them towards evening, or in rain, &c. especially at the beginning of flowering, when the seed is young and tender; as is manifest in the down of dandelion, and other downs; and eminently in the flowers of pim pernel; the opening and shutting of which, are the countryman's weather-wiser; whereby Gerard saith, he foretelleth what weather shall follow the next day; for saith he, 'If the flowers be close shut up, it betokeneth rain and foul weather, contrarywise, if they be spread abroad, fair weather.' Ger. Herb. b. 2. c. 183.

'Est et alia [arbor in Tylis.] similis, foliosior tamen, roseique 'floris; quem noctu comprimens, aperire incipit solis exortu, 'meridie expandit. Incolæ dormire eam dicunt.' Plin. Nat. Hist. l. 12. c. 11.

[b] 'So soon as the seed is ripe, nature taketh several methods for 'its being duly sown; not only in the opening of the uterus, but 'also

others by their agreeable tafte and fmell, and falutary

'alfo in the make of the feed itfelf. For, firft, the feeds of many
'plants, which affect a peculiar foil or feat, as of arum, poppy, &c.
'are heavy and fmall enough, without further care, to fall directly
'down into the ground——But if they are fo large and light, as to
'be expofed to the wind, they are often furnifhed with one or more
'hooks, to ftay them from ftraying too far from their proper place
'——So the feeds of avens have one fingle hook; thofe of agri-
'mony and goofe-grafs; many; both the former loving a warm
'bank; the latter, an hedge for its fupport. On the contrary,
'many feeds are furnifhed with wings or feathers; partly with the
'help of the wind to carry them, when ripe, from off the plant, as
'of afh, &c.—and partly to enable them to make their flight more
'or lefs abroad, that fo they may not, by falling together, come up
'too thick: and that if one fhould mifs a good foil or bed, another
'may hit. So the kernels of pine have wings—yet fhort—whereby
'they fly not into the air, but only flutter upon the ground. But
'thofe of typha, dandelion and moft of the pappous kind—have
'long numerous feathers, by which they are wafted every way.—
'Again, there are feeds which are fcattered not by flying abroad,
'but by being either fpirted or flung away. The firft of thofe are
'wood-forrel, which having a running root, nature fees fit to fow
'the feeds at fome diftance. The doing of which is effected by a
'white fturdy cover; of a tendinous or fpringy nature.—This
'cover, fo foon as it begins to dry, burfts open on one fide, in an
'inftant, and is violently turned infide outward—and fo fmartly
'throws off the feed. The feed of harts-tongue is flung or fhot
'away————by the curious contrivance of the feed-cafe, as in cod-
'ded arfmart, only there the fpring moves and curls inward but
'here outward; viz. every feed cafe—is of a fpheric figure, and
'girded about with a fturdy fpring—The furface of the fpring re-
'fembles a fine fcrew;—fo foon as this fpring is become ftark
'enough, it fuddenly breaks the cafe into two halves, like two
'little cups, and fo flings the feed.' Grew, ib. p. 199. and in tab.
72. all thefe admirable artifices are handfomely reprefented.

ſalutary nature, inviting themſelves to be ſwallowed

'Quin ſi quantitas modica ſeminum [filicis phyllitidis quoque] 'a foliis in ſubjectam chartæ mundæ—ſchedam decutiatur, detergaturve, et deinde in acervum converratur, veſicularum ſeminalium 'plurimis una diſſilientibus, et ſibi invicem alliſis, acervulus vario 'moveri per partes videbitur, non ſecus ac ſi ſyrenibus aut iſtiuſmodi beſtiolis repletus eſſet—quin ſi locus tranquillus ſit, aure proxime admota, crepitantium inter rumpendum vaſculorum ſonitus—'percipietur; et ſi microſcopio chartam oculis oberres, ſemina per 'eam undique ſparſa, et ad notabilem ab acervo diſtantiam projecta 'comperies.' Ray ibid. p. 131.

'The admirable contrivance of nature in this plant is moſt plain: 'for the ſeed-veſſels being the beſt preſerver of the ſeed, it is there 'kept from the injuries of air and earth, till it be rainy, when it is 'a proper time for it to grow, and then it is thrown round the earth, 'as grain by a ſkilful ſower.—When any wet touches the end of the 'ſeed veſſels, with a ſmart noiſe and ſudden leap, it opens itſelf, and 'with a ſpring, ſcatters its ſeed to a pretty diſtance round it, where 'it grows.' Dr. Sloane Voy. to Jamaica, p. 150. of the gentianella flore cœruleo, &c. or ſpirit leaf.

The plants of the cardami ne family, and many others, may be added here, whoſe cods fly open, and dart out their ſeed, upon a ſmall touch of the hand. But the moſt remarkable inſtance is in the cardamine impatiens, 'Cujus ſiliquæ, ſaith Mr. Ray, vel leviter 'tactæ, actutum ejaculantur [ſemina] imo quod longe mirabilius 'videtur, etſi ſiliquas non tetigeris, ſi tamen manum velut tacturus 'proxime admoveas, ſemina in appropinquantem evibrabunt; quod 'tum Moriſonus ſe ſæpius expertum ſcribit, tum Johnſtonus apud 'Gerardum verum eſſe affirmat.' Hiſt. Plant. l. 16. c. 20.

Neither is this proviſion made only for land vegetables, but for ſuch alſo as grow in the ſea. Of which I ſhall give an inſtance from my before-commended friend, Dr. Sloane: 'As to the fuci,—'their ſeed hath been diſcovered, and ſhewed me firſt, by the induſtry lowed and carried about by the birds, and thereby alſo fertilized by paſſing through their bodies[c]; and

'duſtry of the ingenious herbariſt, Mr. Sam. Doody, who found 'on many of this kind, ſolid tubercules, or riſings, in ſome ſea'ſons, wherein were lodged ſeveral round ſeeds, as big as muſtard'ſeed, which, when ripe, the outward membrane of the tubercule 'breaking, leaveth the ſeed to float up and down with the waves. 'The ſeed coming near ſtones, or any ſolid foundation, by means 'of a mucilage it carries with it, ſticks to them, and ſhoots forth 'ligulæ with branches, and in time comes to its perfection and mag'nitude.' Sloan. Voy. Jamaica. p. 50.

But although Mr. Doody had hinted, and conjectured at the thing, yet the firſt that diſcovered the ſeeds in fuci was the before commended Dr. Tancred Robinſon; as may be ſeen by comparing what Mr. Ray ſaith in his Synopſ. Stirp. Brit. p. 6. with his Append. Hiſt. p. 1849. Beſides which fuci, the Dr. tells me, he obſerved veſſels and ſeeds in caralloid ſhrubs, as alſo in ſeveral fungi, not only in the ſpecies of crepitus lupi, but alſo between the lamellæ of other ſpecies, and in that ſubterraneous kind called truffles, whoſe ſeed and veſſels open in the cortex, at ſome ſeaſons he ſaith, like that of mallows in ſhape.

As to the crepitus lupi, I have more than once examined their powder, with thoſe excellent microſcopes of Mr. Wilſon's make; but the moſt ſatisfactory view Mr. Wilſon himſelf gave me; by which I found the ſeeds to be ſo many exceeding ſmall puff balls, with round heads, and longer than ordinary ſharp pointed ſtalks, as if made on purpoſe to prick eaſily into the ground. Theſe ſeeds are intermixed with much duſty matter, and become hurtful to the eyes, probably by their ſharp ſtalks pricking and wounding that tender organ.

[c] The ancient naturaliſts do generally agree, that miſſeltoe is propagated by its ſeeds, carried about by, and paſſing through the body of birds. Thus Theophraſtus, de Cauſ. Plant. l. 2. c. 24. 'T, δὲ ἀπὸ τῶν ὀρνίθων, &c. Initium vero a paſtu avium:—quippe viſco detract

and others not thus taken care of, do many of them by their usefulness in human life, invite the husbandman and gardener carefully to sow and nurse them up.

To this so singular a care about the propagation and conservation of the species of vegetables I might

'detracto confectoque in alvis, quod frigidissimum est, semen cum 'excremento purum dimittitur, et facta mutatione aliqua in arbore 'stercoris causa pullulat, erumpitque, &c. So also Pliny saith, viz. 'Omnino autem satum [viscum] nullo modo nascitur, nec nisi per 'alvum avium redditum, maxime palumbis ac turdi. Hæc est 'natura, et nisi maturatum in ventre avium, non proveniat.' Plin. Hist. l. 16. c. 24. Whether what Theophrastus and Pliny affirm, be conducive to the better fertilizing the seeds of misseltoe I know not; but that it is not of absolute necessity, I can affirm upon mine own experience, having seen the seeds germinate even in the bark of oak. But although they shot above an inch, and seemed to root in the tree, yet they came to nothing, whether destroyed by ants, &c. which I suspected, or whether disagreeing with the oak, I know not. But I since find the matter put out of doubt by Mr. Doody; which see in Mr. Ray's Hist. Plant. Appen. p. 1918.

Nutmegs are said to be fertilized after the same manner, as Tavernier saith was confirmed to him by persons that lived many years in those parts; whose relation was; the nutmeg being ripe, several birds come from the islands towards the south, and devour it whole, but are forced to throw it up again before it be digested: and that the nutmeg then besmeared with a viscous matter, falling to the ground, takes root and produces a tree, which would never thrive was it planted. Tavern. of the Commod. of the Great Mogul. And Monsieur Thevenot, in his travels to the Indies, gives this account: the tree is produced after this manner: there is a kind of birds in the island, that having picked off the green husk, swallow the nuts, which, I might add the nice provifion that is made for their fupport and aid, in ftanding and growing, that they may keep their heads above ground, and not be rotted and fpoiled in the earth themfelves, nor thereby annoy us; but, on the contrary minifter to all their ends, and our ufes, to afford us houfes, utenfils, food [d], phyfic, cloth-

which having been fome time in their ftomach, they void by the ordinary way; and they fail not to take rooting in the place where they fall, and in time grow up to a tree. This bird is fhaped like a cuckow; and the Dutch prohibit their fubjects under pain of death, to kill any of them. Vide Sir T. Pope-Blunt's Nat. Hift.

But Mr. Ray gives a fomewhat different account: 'Hanc fractam '[nucem Mofchatem] variæ quidem aves depafcuntur, fed maxime 'columbæ genus album et parvum, quæ dehifcente nucamento, illec'tæ fuavitate macis, hanc cum nuce eripiunt et devorant, nec nifi 'repleta ingluvie capaciffima faginum deferunt. Noftrates ibi merca'tores columbis iftis nut-eaters five nucivoris nomen impofuerunt. 'Quas autem vorant nuces, poft integras per alvum reddunt. Red'ditæ citius deinde germinant utpote præmaceratæ fervore ventriculi. 'Arbores inde natæ ceu præcociores, facile funt corruptioni obnoxiæ 'fructumque ferunt cæteris multo viliorem, et hac caufa neglectum 'incolis contemptumque, præter macin, quam ad adulterandam me'liorem adhibent.' Ray, Hift. Plant. l. 27. c. 4.

[d] 'Arbores blandioribus fruge fuccis hominem mitigavere. Ex is 'recreans membra olei liquor, virefque potus vini; tot denique fa'pores annui fponte venientes: et menfæ, depugnetur licet earum 'caufa cum feris, et pafti naufragorum corporibus pifces expetantur, 'etiamnum tamen fecundæ. Mille præterea funt ufus earum, fine 'quibus vita degi non poffit. Arbore fulcamus maria, terrafque 'admovemus, arbore exædificamus tecta.' Plin. Nat. Hiftory l. 12. c. 1.

ing, yea, diversion too, by the beauty of their looks, by the fragrancy of their smell, by creating us pleasant shades against the scorching beams of summer, and skreening us against the piercing winds and cold of winter[e].

And it is very observable what admirable provisions are made for this purpose of their support and standing, both in such as stand by their own strength, and such as need the help of others. In such as stand by their own strength, it is by means of the stronger and more ligneous parts equivalent

[e] 'Plantarum usus latissime patet, et in omni vitæ parte occurrit. 'Sine illis laute, sine illis commode non vivitur, at nec vivitur omnino, quæcunque ad victum necessaria sunt, quæcunque ad delicias faciunt e locupletissimo suo penu abunde subministrant. Quanto ex iis mensa innocentior, mundior, salubrior quam ex animalium cæde et laniena? Homo certe natura animal carnivorum non est; nullis ad prædam et rapinam armis instructum, non dentibus exertis et serratis, non unguibus aduncis. Manus ad fructus colligendos dentes ad mandendos comparati. Non legimus ei ante diluvium carnes ad esum concessas. At non victum tantum nobis suppeditant, sed et vestitum, et medicinam, et domicilia, aliaque, ædificia, et navigia, et supellectilem, et focum, et oblectamenta sensuum animique: ex his naribus odoramenta et suffumigia parantur. Horum flores inenarrabili colorum et schematum, varietate, et elegantia, oculos exhilarant, suavissima odorum quos expirant fragrantia spiritus recreant. Horum fructus gulæ illecebræ mensas secundas instruunt, et languentem appetitum excitant. Taceo virorem amoenissimum oculis amicum, quem per prata pascua agros, sylvas spatiantibus objiciunt, et umbras quas contra æstum et solis ardores præbent.' Ray, ib. l. 1. c. 24. p. 46.

ent to the bones in animals, being made not inflexible, as bones; becaufe they would then be apt to break; but of a yielding elaftic nature, to fcape and dodge the violence of the winds, and by means alfo of the branches fpreading handfomely and commodioufly about, at an angle of about 45° gr. by which means they equally fill up, and at the fame time make an æquilibration of the top[f].

And as for fuch vegetables as are weak, and not able to fupport themfelves, it is a wonderful faculty they have, fo readily and naturally to make ufe of the help of their neighbours, embracing

[f] All vegetables of a tall and fpreading growth feem to have a natural tendency to a hemifpherical dilatation, but generally confine their fpreading within an angle of 90° gr. as being the moft becoming and ufeful difpofition of its parts and branches. Now, the fhorteft way to give a moft graceful and ufeful filling to that fpace of dilating and fpreading out, is to proceed in ftrait lines and to difpofe of thofe lines in a variety of parallels, &c. And to do that in a quadrantal fpace, &c. there appears but one way poffible, and that is, to form all the interfections, which the fhoots and branches make, with angles of 45 gr. only. And I dare appeal to all, if it be not in this manner, almoft to a nicety, obferved by nature, &c. A vifible argument that the plaftic capacities of matter are governed and difpofed by an all-wife and infinite agent, the native ftrictneffes and regularities of them plainly fhewing from whofe hand they come. Account of the Origin and Formation of Foffils, Shells, &c. Printed at London, 1705. p. 38, 41.

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bracing and climbing up upon them [g], and using them as crutches to their feeble bodies: some by their odd convolving faculty, by twisting themselves like a screw about others; some advancing themselves by catching and holding with their curious claspers and tendrils, equivalent to the hands; some by striking in their rooty feet; and others

[g] 'In Hedera, surculi et rami hinc inde claviculos, quasi radi-'culas, emittunt, quæ parietibus, vel occurrentibus arboribus veluti 'digitis firmantur, et in altum suspenduntur. Hujusmodi radiculæ 'subrotundæ sunt, et pilis cooperiuntur; et quod mirum est, 'glutinosum fundunt humorem, seu terebinthinum, qua arcte lapi-'dibus nectuntur et agglutinantur. ——Non minori industria natura 'utitur in vite Canadensi, &c. The admirable and curious make of whose tendrils and their feet, see in the illustrious author, Malpig. de Capreolis, &c. p. 48.

Claspers are of a compounded nature, between that of a root and a trunk. Their use is sometimes for support only; as in the claspers of vines, briony, &c. whose branches being long, slender, and fragile, would fall by their own weight, and that of their fruit; but these claspers take hold of any thing that is at hand; which they do by a natural circumvolution which they have; (those of briony have a retrograde motion about every third circle, in the form of a double clasp; so that if they miss one way, they may catch the other.) Sometimes the use of claspers is also for a supply, as in the trunk-roots of ivy; which being a plant that mounts very high, and being of a closer and more compact substance than that of vines, the sap would not be sufficiently supplied to the upper sprouts, unless these assisted the mother-root; but these serve also for support too. Sometimes also they serve for stabiliment, propagation, and shade; for the first of these serve the claspers of cucumbers; for the second, those, or rather the trunk-roots of chamomile; and for all three the trunk-roots of strawberries. Harris Lex. Tech. in verb. Claspers.

others by the emiſſion of a natural glue, closely and firmly adhering to ſomething or other that adminiſters ſufficient ſupport unto them. All which various methods being ſo nicely accommodated to the indigencies of thoſe helpleſs vegetables, and not to be met with in any beſides, is a manifeſt indication of their being the contrivance and work of the Creator, and that his infinite wiſdom and care condeſcends, even to the ſervice, and well-being of the meaneſt, moſt weak, and helpleſs inſenſitive parts of the creation.

In the laſt place, to the uſes already hinted at, I might add a large catalogue of ſuch among vegetables, as are of peculiar uſe and ſervice to the world, and ſeem to be deſigned, as it were, on purpoſe, by the moſt merciful Creator, for the good of man, or other creatures [h]. Among grain I might name the great fertility [i] of ſuch as ſerves

[h] Vegetables afford not only food to irrationals, but alſo phyſic, if it be true which Ariſtotle ſaith, and after him Pliny; which latter, in his 8th book, chap. 27. ſpecifies divers plants made uſe of as ſpecifics, by diverſe, both beaſts and birds; as dittany by wounded deer; celandine by ſwallows to cure the ſore eyes of their young, &c. And if the reader hath a mind to ſee more inſtances of this nature, many of them fanciful enough, he may conſult Merſenne in Geneſ. p. 933.

[i] See before book iv. chap. 11.

for

for bread, the eaſy culture and propagation thereof, and the agreement of every ſoil and climate to it. Among trees, and plants, I might inſtance in ſome that ſeem to be deſigned, as it were, on purpoſe, for almoſt every uſe [k], and convenience ſome

[k] 'Planta hæc unica [aloe Americana] inquit Fr. Hernandez, 'quicquid vitæ eſſe poteſt neceſſarium præſtare facile poteſt, ſi eſſet 'rebus humanis modus. Tota enim illa lignorum, ſepiendorumque 'agrorum uſum præſtat, caules tignorum, folia vero tecta tegendi 'imbricum, lancium: eorundem nervuli et fibræ eundem habent 'uſum ad linteamina, calceos, et veſtimenta conficienda quem apud 'nos linum, cannabis, goſſipium, &c. E mucronibus fiunt clavi 'aculei, ſubulæ, quibus perforandis auribus, macerandi corporis 'gratia, Indis uti mos erat cum dæmonum vacarent cultui; item 'aciculæ, acus, tribuli militares et raſtilla idonea pectendis ſubtegminibus. Præterea e ſucco mananti, cujus evulſis germinibus internis foliiſve tenerioribus cultis [Yztlinis] in mediam cavitatem, 'ſtillat, planta, unica ad 56 interdum amphoras, quod dictu eſt 'mirabile, vina, mel, acetum, ac ſaccharum parantur. [The methods of which he tells.] Idem ſuccus menſes ciet, alvum lenit 'urinam evocat, renes et veſicam emundat. E radice quoque reſtes 'fiunt firmiſſimæ. Craſſiores foliorum partes, truncuſque, decocta 'ſub terra, edendo ſunt apta, ſapiuntque citrea fruſta ſaccharo con- 'dita: quin et vulnera recentia mire conglutinant.—Folia quoque 'aſſa et affecto loco impoſita convulſionem curant, ac dolores leniunt, præcipue ſi ſuccus ipſe calens bibatur, quamvis ab Indica 'proficiſcantur lue, ſenſum hebetant, atque torporem inducunt. 'Radicis ſuccus luem Veneream curat apud Indos, ut Dr. Palmer.' Ray, ib. l. 21. c. 7. See alſo Dr. Sloane's Voyage to Jamaica, page 247.

There are alſo two ſorts of aloe beſides, mentioned by the ſame Dr. Sloane, one of which is made uſe of for fiſhing lines, bowſtrings, ſtockings, and hammocks. Another hath leaves that hold rain water, to which travellers, &c. reſort to quench their thirſt, i ſcarcity of wells, or waters, in thoſe dry countries. Ibid. p. 249.

ſome to heal the moſt ſtubborn and dangerous diſtempers[l], to alleviate and eaſe the pains of[m] our poor infirm bodies, all the world over: and ſome deſigned for the peculiar ſervice and good of particular places, either to cure ſuch diſtempers as are peculiar to them, by growing more plentifully there than elſewhere[n], or elſe to obviate

[l] For inſtance here, I ſhall name the cortex Peruvianus, which Dr. Morton 'calls antidotus in levamen ærumnarum vitæ humanæ 'plurimarum divinitas conceſſa.' De Febr. Exer. v. c. 3. 'In 'ſanitatem gentium proculdubio a Deo O. M. conditus. Cujus 'gratia, arbor vitæ, ſiqua alia, jure merito appellari poteſt. Id. ib. 'c. 7. 'Eheu! quot conviciis Herculea et divini hæc antidotus 'jactabatur!' Ibid.

To this (if we may believe the Eph. Germ. An. 12. Obſ. 74. and ſome other authors) we may add trifolium paludoſum, which is become the panacea of the German and northern nations.

[m] 'Pro doloribus quibuſcunque ſedandis præſtantiſſimi ſemper 'uſus opium habentur quamobrem merito Nepenthe appellari ſolet; 'et remedium vere divinum exiſtit. Et quidem ſatis mirari vix 'poſſumus, quomodo urgente viſceris aut membri cujuſpiam tortura 'inſigni et intolerabili cruciatu, pharmacum hoc, incantamenti 'inſtar, levamen et ἀναλγησίαν ſubitam, immo interdum abſque 'ſomno, aut ſaltem prius quam advenerit, concedit. Porro ad hœc 'magis ſtupendum eſt, quod donec particulæ opiaticæ operari, et 'potentiam ſuam narcoticam exercere continuant, immo etiam 'aliquamdiu poſtquam ſomnus finitur, ſumma alleviatio, et indo-'lentia in parte affecta perſiſtit.' Willis, Phar. Rat. Par. 1. ſect 7. c. 1. ſect. 15.

[n] 'Tales plantarum ſpecies in quacunque regione a Deo creantur 'quales hominibus et animalibus ibidem natis maxime conveniunt: 'im

viate some inconvenience there, or to supply some constant necessity, or occasion, not possible, or at least not easy to be supplied any other way °. It is, for instance, an admirable provision made for some

'imo ex plantarum nascentium frequentia se fere animadvertere posse 'quibus morbis [endemiis] quælibet regio subjecta sit, scribit Soldnander. Sic apud Danos, Frisios, Hollandos, quibus scorbutus 'frequens, cochlearia copiose provenit.' Ray, Hist. Plant. l. 16. chap. 3.

To this may be added Elsner's observations concerning the virtues of diverse things, in his Observations de Vincetoxico Scrophularum remedio. E. Germ. T. 1 obs. 57.

John Benorovius, a physician of Dort, may be here consulted, who wrote a book on purpose to shew, that every country hath every thing serving to its occasions, and particularly remedies afforded to all the distempers it is subject unto. See Benor. Αυταρκεια Batav. sive Introd. ad Medic. indigenam.

° The description Dr. Sloane gives of the wild-pine is, that its leaves are channeled, fit to catch and carry water down into their reservatories; that these reservatories are so made, as to hold much water, and close at top when full, to hinder its evaporation; that these plants grow on the arms of the trees in the woods every where [in those parts,] as also on the barks of their trunks. And one contrivance of nature in this vegetable he saith, is very admirable. The seed hath long and many threads of tomentum, not only that it may be carried every where by the wind,—but also, that it may by those threads, when driven through the boughs, be held fast, and stick to the arms, and exterior parts of the barks of trees. So soon as it sprouts or germinates, although it be on the under part of a bough,——— its leaves and stalk rise perpendicular, or straight up, because if it had any other position, the cistern (beforementioned, by which it is chiefly nourished—) made of the hollow leaves, could not hold water, ſome countries ſubject to drought, that when the waters every where fail, there are vegetables which contain not only moiſture enough to ſupply their own vegetation and wants, but afford drink alſo both to man and other creatures, in their great extremities [p], and a great deal more might be inſtanced in a like nature, and things that bear ſuch plain impreſſes of the divine wiſdom and care, that they manifeſt the ſuper-intendance of the infinite Creator.

Thus I have given a ſketch of another branch of the creation, which, (although one of the meaneſt) yet, if it was accurately viewed, would abundantly manifeſt itſelf to be the work of God. But

water, which is neceſſary for the life and nouriſhment of the plant. —In ſcarcity of water, this reſervatory is neceſſary and ſufficient, not only for the plant itſelf, but likewiſe is very uſeful to men, birds, and all ſorts of inſects, whither they come in troops, and ſeldom go away without refreſhment. Id. ib p. 188. and Phil. Tranſ. No. 251. where a figure is of this notable plant, as alſo in Lowthorp's Abridg. vol. 2. p. 669.

The wild pine ſo called, &c. hath leaves that will hold a pint and a half, or a quart of rain water; and this water refreſhes the leaves and nouriſhes the root. When we find theſe pines, we ſtick our knives into the leaves juſt above the root, and that lets out the water, which we catch in our hats, as I have done many times to my great relief. Dampier's Voy. to Campeachy, c. 2. p. 56.

p Navarette tells us of a tree called the bejuco, which twines about other trees, with its end hanging downwards; and that tra-

traveller's

But becaufe I have been fo long upon the other parts, although lefs than they deferve, I muft therefore content myfelf with thofe general hints I have given; which may however ferve as fpecimens of what might have been more largely faid about this inferior part of the animated creation.

As

vellers cut the nib of it, and prefently a fpout of water runs out from it, as clear as cryftal, enough, and to fpare, for fix or eight men. I drank faith he to my fatisfaction of it, found it cool and fweet, and would drink it as oft as I found it in my way. It is a juice and natural water. It is the common relief of the herdfmen on the mountains? when they are thirfty they lay hold on the bejuco and drink their fill. Collection of Voy. and Trav. volume 1. in the Sup. to Navarette's Account of China, p. 355.

The water-with of Jamaica hath the fame ufes; concerning which, my before-commended friend, Dr. Sloane, favoured me with this account from his original papers; 'This vine growing on dry hills 'in the woods where no water is to be met with, its trunk, if cut 'into pieces two or three yards long, and held by either end to the 'mouth, affords fo plentifully a limpid, innocent and refrefhing 'water, or fap, as gives new life to the droughty traveller or hunter. 'Whence this is very much celebrated by all the inhabitants of thefe 'iflands, as an immediate gift of providence to their diftreffed condi- 'tion.

To this may be added what Mr. Ray takes notice of concerning the birch tree. 'In initiis veris antequam folia prodiere, vulnerata 'dulcem fuccum copiofe effundit quem, fiti preffi paftores in fylvis 'fæpenumero potare folent. Nos etiam non femel eo liquore recrea- 'ti fumus, cum herbarum gratia vaftas peragravimus fylvas, inquit 'Tragus.' Raii Cat. Plant. circa Cantab. in Betula.

As to the inanimate part, ſuch as ſtones, minerals, earth, and ſuch-like, that which I have already ſaid in the beginning ſhall ſuffice.

BOOK XI.

PRACTICAL INFERENCES FROM THE FORE-GOING SURVEY.

HAVING, in the preceding books, carried my ſurvey as far as I care at preſent to engage myſelf, all that remaineth, is to draw ſome inferences from the foregoing ſcene of the great Creator's works, and ſo conclude this part of my intended work.

CHAP.

CHAP. I.

THAT GOD'S WORKS ARE GREAT AND EXCELLENT.

THE firſt inference I ſhall make, ſhall be by way of confirmation of the text, that the 'works of the Lord are great[q].' And this is neceſſary to be obſerved, not againſt the atheiſt only, but all other careleſs, incurious obſervers of God's works. Many of our uſeful labours, and ſome of our beſt modern books, ſhall be condemned with only this note of reproach, that they are about trivial matters[r], when in truth they

[q] 'Equidem ne laudare quidem ſatis pro merito poſſum ejus 'ſapientiam ac potentiam, qui animalia fabricatus eſt. Nam ejuſ-'modi opera non laudibus modo, verum etiam hymnis ſunt majora, 'quæ priuſquam inſpexiſſemus, fieri non poſſe perſuaſum habeamus, 'conſpicati vero, falſos nos opinione fuiſſe comperimus.' Galen. de uſu Part l. 7. c. 15.

[r] 'Num tamen pigere debet lectores, ea intelligere, quem-'admodum ne naturam quidem piguit ea reipſa efficere?' Galen. 'ibid. l. 11. fin.

they are ingenious and noble difcoveries of the works of God. And how often will many own the world in general to be a manifeftation of the infinite Creator, but look upon the feveral parts thereof as only toys and trifles, fcarce deferving their regard! But in the foregoing, I may call it, tranfient view I have given of this lower, and moft flighted part of the creation, I have, I hope, abundantly made out, that all the works of the Lord, from the moft regarded, admired, and praifed, to the meaneft and moft flighted, are great and glorious works, incomparably contrived, and as admirably made, fitted up, and placed in the world. So far then are any of the works of the Lord, even thofe efteemed the meaneft, from deferving to be difregarded, or contemned by us[s], that on the contrary, they deferve, as fhall be fhewn in the next chapter, to be fought out, enquired after, and curioufly and diligently pried into by us; as I have fhewed the word in the text implies.

[s] 'An igitur etiamfi quemadmodum natura hæc, et ejufmodi, 'fumma ratione ac providentia agere potuit, ita et nos imitari aliquando poffemus? Ego vero exiftimo multis noftrum ne id quidem 'poffe, neque enim artem naturæ exponunt: eo enim modo omnino eam admirarentur, fin minus eam faltem non vituperarent.' Galen. ibid. l. 10. c. 3.

CHAP.

CHAP. II.

THAT GOD'S WORKS OUGHT TO BE ENQUIRED INTO, AND THAT SUCH ENQUIRIES ARE COMMENDABLE.

THE Creator doubtlefs did not beftow fo much curiofity and exquifite workmanfhip and fkill upon his creatures, to be looked upon with a carelefs, incurious eye, efpecially to have them flighted or contemned; but to be admired by the rational part of the world, to magnify his own power, wifdom, and goodnefs, throughout all the world, and the ages thereof. And therefore we may look upon it as a great error, not to anfwer thofe ends of the infinite Creator, but rather to oppofe and affront them. On the contrary, my text commends God's works, not only for being great, but alfo approves of thofe curious and ingenious enquirers, that

that ſeek them out, or pry into them. And the more we pry into, and diſcover of them, the greater and more glorious we find them to be, the more worthy of, and the more expreſly to proclaim their great Creator.

COMMENDABLE then are the reſearches, which many amongſt us have, of late years, made into the works of nature, more than hath been done in ſome ages before. And therefore when we are aſked, *Cui bono?* To what purpoſe ſuch inquiries, ſuch pains, ſuch expence? The anſwer is eaſy, It is to anſwer the ends for which God beſtowed ſo much art, wiſdom, and power about them, as well as given us ſenſes to view and ſurvey them; an underſtanding and curioſity to ſearch into them: it is to follow and trace them, when and whither he leads us, that we may ſee and admire his handy-work ourſelves, and ſet it forth to others, that they may ſee, admire, and praiſe it alſo. I ſhall then conclude this inference with what Elihu recommends, Job xxxvi. 24, 25. 'Remember that thou magnify his 'work, which men behold. Every man may 'ſee it, men may behold it afar off."

CHAP.

CHAP. III.

THAT GOD'S WORKS ARE MANIFEST TO ALL; WHENCE THE UNREASONABLENESS OF INFIDELITY.

THE concluding words of the preceding chapter ſuggeſt a third inference, that the works of God are ſo viſible to all the world, and withal ſuch manifeſt indications of the being and attributes of the infinite Creator, that they plainly argue the vileneſs and perverſeneſs of the atheiſt, and leave him inexcuſable. For it is a ſign a man is a wilful, perverſe atheiſt, that will impute ſo glorious a work, as the creation is, to any thing, yea, a mere nothing, as chance is, rather than to God[t]. It

[t] Galen having taken notice of the neat diſtribution of the nerves to the muſcles, and other parts of the face, cries out. 'Hæc enim 'fortunæ

It is a ſign the man is wilfully blind, that he is under the power of the devil, under the government of prejudice, luſt, and paſſion, not right reaſon, that will not diſcern what every one can ſee, what every man may behold afar off, even the exiſtence and attributes of the Creator from his works. For, as 'there is no ſpeech or 'language where their voice is not heard, their 'line is gone out through all the earth, and their 'words to the end of the world.' So all, even the barbarous nations, that never heard of God, have, from theſe his work, inferred the exiſtence of a Deity, and paid their homages to ſome deity, although they have been under great miſtakes in their notions and concluſions about him. But however, this ſhews how naturally and univerſally all mankind agree, in deducing their belief of a God from the contemplation of his work, or, as even

'fortunæ ſunt opera! Cæterum tum omnibus [partibus] immitti, 'tantoſque eſſe ſingulos (nervos) magnitudine quanta particulæ erat 'neceſſe; haud ſcio an hominum ſit ſobriorum ad fortunam opificem 'id revocare. Alioqui quid tandem erit, quod cum providentia et 'arte efficitur? Omnino enim hoc ei contrarium eſſe debet, quod 'caſu ac fortuito fit.' And afterwards, 'Hæc quidem atque ejuſ-'modi artis ſcil, ac ſapientiæ opera eſſe dicemus, ſi modo fortunæ 'tribuenda ſunt quæ ſunt contraria; fietque jam quod in proverbiis '—Fluvii ſurſum fluent; ſi opera quæ nullum habent ornamen-'tum, neque rationem, neque modum artis eſſe; contraria vero 'fortunæ duxerimus, &c. Galen. ubi ſupra, l. 11. c. 7.

even as Epicurus himself, in Tully [u] saith, from 'a notion that nature itself hath imprinted upon 'the minds of men. For, saith he, what nation 'is there, or what kind of men, that without 'any teaching or instructions, have not a kind of 'anticipation, or pre-conceived notion of a 'Deity?'

An atheist therefore, if ever there was any such, may justly be esteemed a monster among rational beings; a thing hard to be met with in the whole tribe of mankind; an opposer of all the world [w]; a rebel against his human nature and reason, as well as against his God.

But above all, monstrous is this, or would be, in such as have heard of God, who have had the benefit of the clear gospel-revelation. And still more

[u] 'Primum esse Deos, quod in omnium animis,' &c. And a little after, 'Cum enim non instituto aliquo, aut more, aut lege sit 'opinio constituta, maneatque ad unum omnium firma consensio, 'intelligi necesse est, esse Deos, quoniam insitas eorum, vel potius 'innatas cognitiones, habemus. De quo autem omnium natura 'consentit, id verum esse necesse est. Esse igitur Deos confitendum 'est.' Cicer. de Nat. Deor. l. 1. c. 16, 17.

[w] The atheist in denying a God, doth, as Plutarch saith, endeavour—'Immobilia movere, et bellum inferre non tantum longo 'tempori, sed et multis hominibus, gentibus, et familiis, quas religiosus deorum cultus, quasi divino furore correptas, tenuit.' Plutar. de Iside.

more monſtrous this would be, in one born and baptized in the Chriſtian church, that hath ſtudi-ed nature, and pried farther than others into God's works. For ſuch an one, if it be poſſible for ſuch to be, to deny the exiſtence, or any of the attributes of God, would be a great argument of the infinite inconvenience of thoſe ſins of intemperance, luſt, and riot, that hath made the man abandon his reaſon, his ſenſes, yea, I had almoſt ſaid his very human nature, to engage him thus to deny the being of a God.

So alſo it is much the ſame monſtrous infidelity at leaſt betrays the ſame atheiſtical mind, to deny God's providence, care, and government of the world, or, which is a ſpawn of the ſame Epicurean principles, to deny final cauſes [z], in God's works of creation; or with the profane, in Pſal. lxxiii. 11. to ſay, 'How doth God now? and is there 'knowledge in the moſt High?' For, as the

[z] Galen having ſubſtantially refuted the Epicurean principles of Aſclepiades, by ſhewing his ignorance in anatomy and philoſophy, and by demonſtrating all the cauſes to be evidently in the works of nature, viz. final, efficient, inſtrumental, material, and formal cauſes, concludes thus againſt his fortuitous atoms, 'Ex quibus in-'telligi poteſt conditorem noſtrum in formandis particulis unum 'hunc ſequi ſcopum, nempe ut quod melius eſt eligat.' Galen. de uſu Part. l. 6. c. 13.

witty and eloquent Salvian ſaith [y], 'They that 'affirm nothing is ſeen by God, will, in all probability, take away the ſubſtance, as well as 'ſight of God.—But what ſo great madneſs, 'ſaith he, as that when a man doth not deny 'God to be the Creator of all things, he ſhall 'deny him to be the governor of them? Or 'when he confeſſeth him to be the maker, he 'ſhould ſay, God neglecteth what he hath ſo 'made?

[y] De Gubern. Dei. l. 4. p. 124. meo libro, alſo l. 7. c. 14.

CHAP.

CHAP. IV.

THAT GOD'S WORKS OUGHT TO EXCITE US TO FEAR AND OBEDIENCE TO GOD.

SINCE the works of creation are all of them ſo many demonſtrations of the infinite wiſdom and power of God, they may ſerve to us as ſo many arguments exciting us to the conſtant fear of God, and to a ſteady, hearty obedience to all his laws. And thus we may make theſe works as ſerviceable to our ſpiritual intereſt, as they all are to our life, and temporal intereſt. For if whenever we ſee them, we would conſider that theſe are the works of our infinite Lord and Maſter, to whom we are to be accountable for all our thoughts, words, and works, and that in theſe we may ſee his infinite power and wiſdom; this would check us in ſinning, and excite us to ſerve and pleaſe him who is above all controul, and who hath our life and whole happineſs in his power. After this manner God himſelf argues with his own

own 'foolish people, and without understanding, 'who had eyes, and saw not, and had ears, and 'heard not,' Jer. v. 21, 22. 'Fear ye not me? 'saith the Lord: will ye not tremble at my pre- 'sence, who have placed the sand for the bound 'of the sea, by a perpetual decree, that it can- 'not pass it; and though the waves thereof toss 'themselves, yet can they not prevail; though 'they roar, yet can they not pass over it?'

This was an argument that the most ignorant, stupid wretches could not but apprehend; that a Being that had so vast and unruly an element, as the sea, absolutely at his command, ought to be feared and obeyed, and that he ought to be considered as the sovereign Lord of the world, on whom the world's prosperity and happiness did wholly depend; ver. 24. 'Neither say they in 'their heart, let us now fear the Lord our God, 'that giveth rain, both the former and the latter 'in his season: he reserveth unto us the appoint- 'ed weeks of the harvest.'

CHAP. V.

THAT GOD'S WORKS OUGHT TO EXCITE US TO THANKFULNESS.

AS the demonſtrations which God hath given of his infinite power and wiſdom ſhould excite us to fear and obedience; ſo I ſhall ſhew in this chapter, that the demonſtrations which he hath given of his infinite goodneſs in his works, may excite us to due thankfulneſs and praiſe. It appears throughont the foregoing ſurvey, what kindneſs God hath ſhewn to his creatures in providing every thing conducing to their life, proſperity, and happineſs [z]; how they are all

[z] 'Si pauca quis tibi donaſſet jugera, accepiſſe te diceres benefi-'cium: immenſa terrarum late patentium ſpatia negas eſſe benefi-'cium? Si pecuniam tibi aliquis donaverit,——beneficium vocabis; 'tot metalla defodit, tot flumina emiſit in aera, ſuper quæ decurrunt 'ſola aurum vehentia; argenti, æris, ferri immane pondus omnibus 'locis

all contrived and made in the beſt manner, placed in the fitteſt places of the world for their habitation and comfort; accoutered in the beſt manner, and accommodated with every, even all the minuteſt things that may miniſter to their health, happineſs, office, occaſions, and buſineſs in the world.

Upon which account, thankfulneſs and praiſe is ſo reaſonable, ſo juſt a debt to the Creator, that the pſalmiſt calleth upon all the creatures to praiſe God, in Pſalm cxlviii. 'Praiſe him all his 'angels, praiſe him all his hoſts; ſun, moon, 'ſtars of light, heavens of heavens, and waters 'above the heavens.' The reaſon given for which is, ver. 5, 6. 'For he commanded, and 'they were created; he hath alſo eſtabliſhed 'them for ever and ever; he hath made a decree 'which they ſhall not paſs.' And not theſe celeſtials alone, but the creatures of the earth and

'locis obrutum, cujus inveſtigandi tibi facultatem dedit,—negas te 'accepiſſe beneficium? Si domus tibi donetur, in qua marmoris ali'quid reſplendeat, &c. Num mediocre munus vocabis; Ingens 'tibi domicilium, ſine ullo incendii, aut ruinæ metu ſtruxit, in quo 'vides non tenues cruſtas—ſed integras lapidis pretioſiſſimi moles, '&c. negas te ullum munus accepiſſe? Et cum iſta quæ habes mag'no æſtimes, quod eſt ingrati hominis, nulli debere te judicas? 'Unde tibi iſtum quem trahis ſpiritum? Unde iſtam, per quam duc'tus vitæ tuæ diſponis atque ordinas, lucem.' &c. Senec. de Benef l. 4. c. 6.

and waters too, even the meteors, ‘ Fire and ‘ hail, ſnow and vapours, ſtormy winds fulfil‑ ‘ ling his word.’ Yea, the very ‘ mountains and ‘ hills, trees, beaſts, and all cattle, creeping ‘ things, and flying fowl.’ But in a particular manner, all the ranks and orders, all the ages and ſexes of mankind are charged with this duty; ‘ Let them praiſe the name of the Lord, ‘ for his name alone is excellent; his glory is ‘ above the earth and heavens,’ verſe 13.

And great reaſon there is we ſhould be excited to true and unfeigned thankfulneſs and praiſe * to this our great benefactor, if we reflect upon what hath been ſhewn in the preceding ſurvey, that

* ‘ Tempeſtivum tibi jam fuerit, qui in hiſce libris verſaris con‑ ‘ ſiderare, in utram familiam recipi malis, Platonicamne ac Hippo‑ ‘ craticam, et aliorum virorum, qui naturæ opera mirantur; an ‘ eorum qui ea inſectantur, quod non per pedes natura conſtituit ‘ effluere excrementa.’ Of which, having told a ſtory of an ac‑quaintance of his, that blamed nature on this account, he then goes on: ‘ At vero ſi de hujuſmodi pecudibus plura verba fecero, melioris ‘ mentis homines merito mihi forte ſuccenſeant, dicantque me pol‑ ‘ luere ſacrum ſermonem, quum ego CONDITORIS noſtri verum ‘ hymnum compono, exiſtimoque in eo veram eſſe pietatem,—ut ſi ‘ noverim ipſe primus, deinde et aliis expoſuerim, quænam ſit ipſius ‘ ſapientia, quæ virtus, quæ bonitas. Quod enim cultu convenienter ‘ exornaverit omnia, nullique bona inviderit, id perfectiſſimæ bon‑ ‘ itatis nobis eſt celebranda. Hoc autem omne inveniſſe quo pacto ‘ omnia potiſſimum adornarentur, ſummæ ſapientiæ eſt: effeciſſe ‘ autem omnia, quæ voluit, virtutis eſt invictæ.’ Galen. de uſu Part. l. 3. c. 10.

that the Creator hath done for man alone, without any regard to the reſt of the creatures, which ſome have held were made for the ſake of man. Let us but reflect upon the excellence and immortality of our ſoul; the incomparable contrivance, and curious ſtructure of our body; and the care and caution taken for the ſecurity and happineſs of our ſtate, and we ſhall find, that among the whole race of beings, man hath eſpecial reaſon to magnify the Creator's goodneſs, and with ſuitable ardent affections to be thankful unto him.

CHAP. VI.

THAT WE OUGHT TO PAY GOD ALL DUE HOMAGE, AND WORSHIP, PARTICULARLY THAT OF THE LORD'S DAY.

FOR a conclufion of thefe lectures, the laft thing I fhall infer, from the foregoing demonftration of the being and attributes of God, fhall be, that we ought to pay God all that homage and worfhip which his right of creation and dominion entitles him unto, and his great mercies call for from us. And forafmuch as the Creator appointed, from the very creation, one day in feven to his fervice, it will not therefore be improper to fay fomething upon that fubject: and if I infift fomewhat particularly and largely thereon, the congruity thereof to the defign of thefe lectures, and the foregoing demonftration, together with the too great inadvertency about, and neglect of this ancient, univerfal, universal, and most reasonable and necessary duty, will, I hope, plead my excuse. But that I may say no more than is necessary on this point, I shall confine myself to two things; the time God hath taken, and the business then to be performed.

I. The time is one day in seven, and one of the ancientest appointments it is, which God gave to the world. For, as soon as God had finished his six days works of creation, it is said, Gen. ii. 2, 3. 'He rested on the seventh day 'from all his work which he had made. And 'God blessed the seventh day, and sanctified it, 'because that in it he had rested from all his 'work.' This sanctification [c], and blessing the seventh day, was setting it apart, as a day of distinction from the rest of the week-days, and appropriating it to holy uses and purposes, namely, the commemoration of that great work of the creation, and paying homage and worship to that infinite Being, who was the effector of it.

This day, thus consecrated from the beginning, for the celebration of the 'τῦ κόσμυ γενέσιον, the

[c] קדש Usibus divinis accommodavit, a communi et profano 'usu segregavit, in usum sacrum ad cultum Dei destinavit.' Kirch. 'Concord. p. 1336. 'Destinari ad aliquid, sacrari,' &c. Buxtorf, in verbo.

'world's birth-day,' as Philo calls it, was probably, in ſome meaſure, forgotten in the following wicked ages, which God complains of, Gen. vi. 5. and ſo after the flood likewiſe. But after the return out of Egypt, when God ſettled the Jewiſh polity, he was pleaſed to renew this day, and to eſtabliſh it for a perpetual ſtanding law. And accordingly it was obſerved down to our bleſſed Saviour's time, countenanced, and ſtrictly obſerved, by our great Lord and Maſter himſelf, and his apoſtles and diſciples, in and after his time; and although for good reaſons, the day was changed by them, yet a ſeventh day hath been conſtantly obſerved in all ages of Chriſtianity down to our preſent time.

Thus we have a day appointed by God himſelf, and obſerved throughout all ages, except ſome few, perhaps, which deſerve not to be brought into example.

And a wiſe deſignation of time this is, well becoming the divine care and precaution; ſerving for the recruiting our bodies, and diſpatching our affairs, and at the ſame time to keep up a ſpiritual temper of mind. For, by allowing ſix days to labour, the poor hath time to earn his bread, the man of buſineſs time to diſpatch his affairs, and every man time for the

work

work of his refpective calling. But had there been more, or all our time allotted to labour and bufinefs, and none to reft and recruit, our bodies and fpirits would have been too much fatigued and wafted, and our minds have been too long engaged about worldly matters, fo as to have forgotten divine things. But the infinitely wife Ruler of the world, having taken the feventh part of our time to his own fervice, hath prevented thefe inconveniencics, hath given a relaxation to ourfelves; and eafe and refrefhment to our wearied beafts, to poor fatigued flaves, and fuch as are under the bondage of avaricious, cruel mafters. And this is one reafon Mofes gives of the refervation and reft on the feventh day. Deut. v. 13, 14, 15. 'Six days 'fhalt thou labour, and do all thy work; but 'the feventh is the fabbath of the Lord thy 'God; in it thou fhalt not do any work, thou, 'nor thy children, fervants, cattle, or ftranger, 'that thy man-fervant and maid-fervant may 'reft as well as thou. And remember, that 'thou waft a fervant, &c. therefore the Lord thy 'God commanded thee to keep the fabbath-day.' That carnal, greedy people, fo bent upon gain, without fuch a precept, would have fcarce favoured their own bodies, much lefs have had mercy upon their poor bondfmen and beafts; but by this wife provifion, this great burden was taken

taken off. But on the other hand, as a longer liberty would too much have robbed the maſter's time, and bred idleneſs, ſo by this wiſe proviſion, of only one day of reſt, to ſix of labour, that inconveniency was alſo prevented.

Thus the wiſe Governor of the world hath taken care for the diſpatch of buſineſs. But then as too long engagement about worldly matters would take off mens minds from God and divine matters, ſo by this reſervation of every ſeventh day, that great inconvenience is prevented alſo; all being then bound to worſhip their great Lord and Maſter, to pay their homages and acknowledgments to their infinitely kind Benefactor; and, in a word, to exerciſe themſelves in divine. religious buſineſs, and ſo keep up that ſpiritual temper of mind, that a perpetual, or long application to the world would deſtroy.

This, as it was a good reaſon for the order of a Sabbath to the Jews; ſo is as good a reaſon for our Saviour's continuance of the like time in the Chriſtian church.

And a law this is, becoming the infinitely wiſe Creator and Conſervator of the world; a law, not only of great uſe to the perpetuating the

the remembrance of thofe greateft of God's mercies then commemorated, but alfo exactly adapted to the life, occafions, and ftate of man; of man living in this, and a-kin to another world: a law well calculated to the difpatch of our affairs, without hurting our bodies or minds. And fince the law is fo wife and good, we have great reafon then to practife carefully the duties incumbent upon us; which will fall under the confideration of the

II. Thing I propofed, the bufinefs of the day, which God hath referved to himfelf. And there are two things enjoined in the commandment, a ceffation from labour and worldly bufinefs; and that we remember to keep the day holy.

Firft, There muft be a ceffation from worldly bufinefs, or a reft from labour, as the word *fabbath*[a] fignifies. 'Six days thou fhalt do all thy 'work, but the feventh is the Sabbath of the 'Lord thy God, (not thy day, but his,) in which 'neither thou, nor any belonging to thee, fhall 'do any work.' In which injunction it is obfervable, how exprefs and particular this commandment is, more than others, in ordering all forts of perfons to ceafe from work.

[a] שבת Ceffatio, requies.

Secondly, WE muſt remember to keep the day holy. Which remembrance is another thing alſo in this, more than in the other commandments, and implies,

1ſt, THAT there is great danger of our forgetting, neglecting, or being hindered from keeping the day holy, either by the infirmity and carnality of our own nature, or from the avocations of the world.

2dly, THAT the keeping it holy is a duty of more than ordinary conſequence and neceſſity. And of greateſt conſequence this is,

1. To perpetuate the remembrance of thoſe grand works of God commemorated on that day in the firſt ages of the world, the creation; in the middle ages, the creation and delivery from Egypt; and under Chriſtianity, the creation and redemption by Chriſt. Which mercies, without ſuch frequent occaſions, would be ready to be forgotten, or diſregarded, in ſo long a tract of time, as the world hath already ſtood, and may, by God's mercy, ſtill ſtand.

2. To keep up a ſpiritual temper of mind, by thoſe frequent weekly exerciſes of religion, as hath been already mentioned.

3. To

3. To procure God's bleffing upon the labours and bufinefs of our fix days, which we can never expect fhould be profperous, if we are negligent of God's time. For, how can we expect God's bleffing, upon a week fo ill begun, with a neglect, or abufe of God's firft day? And therefore if we become unprofperous in the world; if loffes, troubles, or dangers befal us, let us reflect how we have fpent the Lord's day; whether we have not wholly neglected it, or abufed it in riot, or made it a day for taking journies, for more private bufinefs, and lefs fcandalous labour, as the cuftom of too many is.

THUS having fhewn what reafon there is to remember to keep holy the day dedicated to God, I fhall confider how we are to keep it holy, and fo conclude. Now, the way to keep it holy, is not by bare refting from work; for that, as a father faith is, 'Sabbatum boum et afinorum, 'a fabbath of beafts:' but holy acts are the proper bufinefs of a holy day, celebrated by rational beings. Among all which, the grand principal, and moft univerfally practifed, is the public worfhip of God, the affembling at the public place of his worfhip, to pay, with our fellow creatures, our homages, thanks, and praifes to the infinite Creator and Redeemer of the world. This, as it is the moft reafonable

fervice,

ſervice, and proper buſineſs for this day, ſo it is what hath been the practice of all ages. It was as early as Cain and Abel's days, Gen. iv. 3. what was practiſed by religious perſons in the following ages, till the giving of the law; and at the giving of that, God was pleaſed to order places, and his particular worſhip, as well as the ſeventh day. The tabernacle and temple were appointed by God's expreſs command; beſides which there were ſynagogues all over the nation; ſo that in our Saviour's time, every great town, or village, had one, or more in it, and Jeruſalem 460, or more [*].

The worſhip of theſe places, our bleſſed Saviour was a conſtant and diligent frequenter of. It is ſaid, 'He went about all the cities and 'villages, teaching in their ſynagogues, and 'preaching, and healing, &c. Matth. ix. 35. And St. Luke reporteth it as his conſtant cuſtom and practice, Luke iv. 16. 'And as his cuſtom 'was, he went into the ſynagogue on the Sabbath-day.'

Having thus mentioned the practice of Chriſt, it is not neceſſary I ſhould ſay much of the practice of his apoſtles, and the following purer

* See Lightfoot's Works. vol. 2. p. 35, and 646.

ages

ages of Christianity, who, in short, as their duty was, diligently followed their great master's example. 'They did not think it enough to read and 'pray, and praise God at home, but made conscience of appearing in the public assemblies, 'from which nothing but sickness and absolute 'necessity did detain them; and if sick, or in 'prison, or under banishment, nothing troubled 'them more, than that they could not come to 'church, and join their devotions to the com'mon services. If persecution at any time 'forced them to keep a little close; yet no 'sooner was there the least mitigation, but they 'presently returned to their open duty, and pub'lickly met all together. No trivial pretences, 'no light excuses, were then admitted for any 'one's absence from the congregation, but ac'cording to the merit of the cause, severe cen'sures were passed upon them,' &c. to express it in the words of one of our best antiquaries[f].

The public worship of God then is not a matter of indifference, which men have in their own power to do, or omit, as they please; neither is it enough to read, pray, or praise God at home, unless some inevitable necessity hindereth; because the appearing in God's house, on his day, is an act of homage and fealty, due to the

[f] Dr. Cave's Primitive Christianity, p. 1. cap. 7.

Creator,

Creator, a right of sovereignty we pay him. And the with-holding those rights and dues from God is a kind of rejecting God, a disowning his sovereignty, and a withdrawing our obedience and service. And this was the very reason why the profanation of the Sabbath was punished with death among the Jews, the Sabbath being a sign, or badge of the God they owned and worshipped [g]. Thus Exod. xxxi. 13. 'My Sab-'baths ye shall keep; for it is a SIGN between 'me

[g] At this day it is customary for servants to wear the livery of their masters, and others to bear badges of their order, profession, servility, &c. So in former ages, and diverse countries, it was usual to bear badges, marks, and signs on divers occasions. In Ezek. ix. 4. 'A 'mark was to be set on the forehead of those that lamented the abo-'minations of the city.' The like was to be done upon them in Rev. vii. 3. and ix. 4. So the worshippers of the beast, Rev. xiii. 16. were to receive a Χάραγμα, 'A mark in the right hand, on their 'foreheads.' Those Χαράγματα, Σφραγῖδες, Badges, &c. were very common. Soldiers and slaves bare them in their arms or foreheads; such as were matriculated in the heteriae, or companies, bare the badge or mark of their company; and whoever listed himself into the society of any of the several gods, received a Χάραγμα, or a mark in his body, (commonly made with red hot needles or some burning in the flesh,) of the God he had listed himself under. And after Christianity was planted, the Christians had also their sign of the cross. And not only marks in their flesh, badges on their clothes, &c. were usual; but also the dedication of days to their imaginary deities. Not to speak of their festivals, &c. the days of the week were all dedicated to some of their deities. Among the Romans, Sunday and Monday, to the Sun and Moon; Tuesday to Mars; Wednesday to Mercury, &c. So our Saxon ancestors did the same Sunday

'me and you, throughout your generations; 'that ye may know that I am the Lord, that doth 'sanctify you;' or, as the original may be rendered, 'A sign to acknowledge, that I JEHOVAH 'am your Sanctifier, or, your GOD:' for, as our learned Mede observes, 'To be the Sanc-'tifier of a people, and to be their God, is all 'one.' So likewise very expresly in Ezek. xx. 20. 'Hallow my sabbaths, and they shall be a 'sign between me and you, that ye may know 'that I am the Lord your God;' or rather as before, 'to acknowledge that I JEHOVAH am 'your GOD.'

THE sabbath being thus a sign, a mark, or badge, to acknowledge God to be their God, it follows, that a neglect or contempt of that day redounded to God; to slight that, was slighting God; to profane that, was to affront God; for the punishment of which, what more equitable penalty than death! And although under Christianity, the punishment is not made capital, yet have we no less reason for the strict observance of this holy day than the Jews, but rather greater

Sunday and Monday, as the Romans did to the Sun and Moon; Tuesday to Tuysco; Wednesday to Woden; Thursday to Thuoer; Friday to Friga; and Saturday to Seater: an account of which deities, with the figures under which they were worshipped, may be met with in our learned Verstegan, chap. 3. p. 68.

greater reafons. For the God we worfhip is the fame: if after the fix days'labour, he was, by the feventh, owned to be God, the Creator; no lefs is he by our Chriftian Lord's-day: if by the celebration of the Sabbath, the rememberance of their deliverance from the Egyptian bondage was kept up, and God acknowleged to be the effector thereof; we Chriftians have a greater deliverance; we own our deliverance from fin and Satan, wrought by a greater Redeemer than Mofes, even the bleffed Jefus, whofe refurrection and the completion of our redemption thereby, was performed on the Chriftian Lord's-day.

And now, to fum up, and conclude thefe inferences, and fo put an end to this part of my furvey: fince it appears, that the works of the Lord are fo great, fo wifely contrived, fo accurately made, as to deferve to be enquired into; fince they are alfo fo manifeft demonftrations of the Creator's being and attributes, that all the world is fenfible thereof, to the great reproach of atheifm: what remaineth, but that we fear and obey fo great and tremendous a Being! that we be truly thankful for, and magnify and praife his infinite mercy, manifefted to us in his works! And forafmuch as he hath appointed a day on purpofe, from the beginning, for thefe fervices, that we may weekly meet together, commemo-

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rate and celebrate the great work of creation, that we may pay our acts of devotion, worſhip, homage, and fealty to him; and ſince this is a wiſe and excellent diſtribution of our time, what ſhould we do, but conſcientiouſly and faithfully pay God theſe his rights and dues; and as carefully and diligently manage God's time, and diſcharge his buſineſs then, as we do our own upon ſix days; particularly that with the pious pſalmiſt, 'We love the habitation of God's houſe, and 'the place where his honour dwelleth;' and therefore take up his good reſolution in Pſal. v. 7, with which I ſhall conclude; 'But as for me I 'will come into thine houſe in the multitude of 'thy mercy, and in thy fear will I worſhip 'towards thy holy temple.'

Now, to the ſame infinite God, the omnipotent Creator and Preſerver of the world, the moſt gracious Redeemer, Sanctifier, and Inſpirer of mankind, be all honour, praiſe, and thanks, now and for ever, Amen.

ASTRO-THEOLOGY,

OR, A

DEMONSTRATION

OF

The Being and Attributes of God,

FROM A

SURVEY OF THE HEAVENS.

Illustrated with COPPER PLATES,

By W. DERHAM, D. D. late Canon of WINDSOR,
Rector of UPMINSTER in ESSEX, and F. R. S.

MDCCLXXXVI.

TO

His ROYAL HIGHNESS

GEORGE,

PRINCE of *Wales*, PRINCE Electoral of *Brunswick-Lunenburg*, &c.

Duke of Cornwall and Rothsay, Duke and Marquis of Cambridge, Earl of Chester, Milford-Haven, and Carreck, Viscount North-Allerton, Baron of Tewksbury and Renfrew, Lord of the Islands, and Steward of Scotland, and Knight of the most Noble Order of the Garter.

GREAT SIR,

YOUR Royal Highness having done me so great an honour, as to take this Book under your Patronage, with great humility and thankfulness I lay it at your feet; not doubting but that (whatever my performance is) the sub-

† ject

ject will be acceptable, it being a vindication of the existence and attributes of that infinite Being, to whom your Royal Highness hath no less piously than justly ascribed your great Royal Father's and your Family's peaceable accession to the crown, and dignity to these realms.

That the blessings of the same most merciful Being may be perpetuated to your Royal Highness, and all yours, is the hearty prayer of,

Most Illustrious Sir,

Your Royal Highness's

Most Humble

Obedient Servant;

W. DERHAM.

TO THE

READER.

NOtwithſtanding that a book is more compleat and valuable by additions and amendments, yet I think that many and great additions are an hardſhip and injuſtice to the purchaſers of a former edition; and therefore have in this, and the foregoing editions, avoided it as much as I well could, although ſome of my learned friends would have perſuaded me to it, and alſo contributed their obſervations.

But yet from what I have ſaid in the Preliminary Diſcourſe, p. 177, it will, I doubt not, be expected, that I ſhould give ſome account of the obſervations, which the long and good glaſſes in my hands have afforded me ſince the laſt edition of this book.

But I have little to boaſt of here, having (beſides the old former complaint of the want of a long pole to manage Mr. Huygens's glaſs with) many great hinderances in my obſervations, partly by a very dangerous fit of ſickneſs, which hung long about me; and partly by my neceſſary affairs calling me to matters of another nature.

But ſome of the moſt conſiderable of my obſervations were theſe.

1. Viewing Venus with Mr. Huygens's glaſs divers nights, when near her perigee, and much horned, I thought I ſaw anfractus or roughneſſes on the concave part of the enlightened edge, (ſuch as we ſee in the new moon) which I have repreſented as nearly as I could in fig. 12.

2. In my frequent views of Jupiter, I find his belts to have great variations; that they change their places; that their breadths alter, being ſometimes broader, ſometimes conſiderably narrower; that ſometimes they are more in number, ſometimes fewer, ſometimes they are darker and blacker, ſometimes thin and only like a miſt. Towards the poles of Jupiter are the greateſt alterations, there being ſometimes few or no belts towards one or the other pole; ſometimes one quite acroſs the polar parts, another reaching but half, or a part of the way. And even about the middle, or equatorial parts of Jupiter, where there are always belts,(and commonly two) yet theſe vary conſiderably. Sometimes they are nearer one another, ſometimes further aſunder; ſometimes as conſiderably broader, eſpecially that neareſt the middle; ſometimes as conſiderably

narrower;

narrower; ſometimes they both advance towards one pole, and then recede towards the other oppoſite pole. Of many of theſe appear-pearances I took draughts, and deſigned to have enquired whether they had certain periods; but want of health and leiſure prevented me.

And not only the belts, but the ſpots alſo of Jupiter vary greatly; I do not mean the ſpots occaſioned by the ſhade of the ſatellites, but ſuch as are on the very diſk; which are ſometimes of one form, ſometimes of another; and oftentimes none to be ſeen at all, although the ſame face of Jupiter ſhould be towards us.

3. The laſt thing I ſhall mention is the nebuloſe, which are thoſe glaring whitiſh appearances, ſeen with our teleſcopes in Andromeda's girdle, Hercules's back, Antinous's foot, Orion's ſword, in the Centaur, Sagittary, &c. which appear through the teleſcope ſomewhat after the manner as *Cor Cancri* doth to the naked eye.

Theſe nebuloſe I have often viewed with glaſſes of very different lengths, particularly that in *Pede Antinoi* with Mr. Huygens's: but I confeſs that I could never diſcern what they are; neither indeed could I perceive any great difference in their appearances through a very good glaſs of about

about 14 foot, and others of 30 and 40 foot, yea, Mr. Huygens's of 126.

But indeed the grand obſtacle to all my views with Mr. Huygens's glaſs was the vapours near the horizon, which not only obſcured the object, but cauſed ſo great a trembling and dancing thereof, as made it no leſs difficult to be diſtinctly and accurately viewed, than a thing held in the hand is, when danced and ſhaken backwards and forwards. By this means my expectations from Mr. Huygens's glaſs were frequently fruſtrated, excepting in nights that were more than ordinarily ſerene and clear; which was commonly in ſuch as were the moſt intenſely froſty and cold.

Finding it therefore unlikely that I ſhould do much more with Mr. Huygens's glaſs than I had done, I reſtored it to the Royal Society which lent it me, (and to whom Mr. Huygens bequeathed it by his laſt will) contenting myſelf with the views it had given me, and that I had diſcovered it to be an excellent glaſs; which Dr. Hook, and ſome others of our beſt judges, took to be good for nothing.

And now having given this account of my obſervations, and alſo ſhewed what hindered my

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compleating of them, (which may excite farther enquiries, as well as ſerve to vindicate myſelf) I ſhall recommend theſe things to ſuch as have good glaſſes, particularly to the diligence and accuracy of my very ingenious friend the Rev. Mr. Pound, into whoſe hands the Royal Society have put that noble bequeſt of Mr. Huygens, and who is ſo well accommodated for raiſing and uſing that glaſs, as to have ſeen (among other conſiderable things) the five ſatellites of Saturn; which, I confeſs, I could never reach, nor above three of them that I could be ſure were ſatellites: I ſay, that I could be ſure were ſuch, becauſe it is not very eaſy to diſtinguiſh which are ſatellites, and which are ſmall teleſcopic ſtars, which very frequently ſhew themſelves in a glaſs of ſuch goodneſs as that is. I remember that I once verily thought I had found out ſeven ſatellites of Saturn, with this very glaſs of Mr. Huygens, ſo regularly were they placed in reſpect of Saturn. But when I came to examine them the following nights, I found that there were really no more than two ſatellites, the reſt being ſmall fixt ſtars. But Mr. Pound's ſkill and exactneſs in ſuch obſervations is, I know, ſo great, (and I may add that of my ſagacious friend Dr. Halley too, who, I hear, hath ſeen the ſame) that I do not ſay this by way of caution to them, although it may ſerve as ſuch to many others.

And now for a close, I shall take this opportunity of publicly owning, with all honour and thankfulness, the generous offer made me by some of my friends, eminent in their stations, as well as skill and abilities in the laws, who would have made me a present of the May-pole in the Strand (which was to be taken down) or any other pole I thought convenient for the management of Mr. Huygens's glass. But as my incapacity of accepting the favour of those noble Mecœnates, hath been the occasion of that excellent glass being put into better hands; so, I assure myself, their expectations are abundantly answered, by the number and goodness of the observations that have been, and will be made therewith.

A PRE-

A PRELIMINARY DISCOURSE,

CONCERNING

THE SYSTEMS OF THE HEAVENS, THE HABITABILITY OF THE PLANETS, AND A PLURALITY OF WORLDS, USEFUL FOR THE READING OF THE FOLLOWING BOOK.

MY Physico-Theology having met with so quick a sale as to come to a third impression before the year was expired, but especially the solicitations of many learned men, both known and unknown, have given me great encouragement to fulfil my promise, in sending abroad this other part, relating to the heavens: which should sooner have seen the light, but that I was minded not to interrupt the reader's patience with many notes (which I could not well avoid in my Physico-Theology, and which my rough draught of this was burthened with) and therefore I threw the greatest part of them into the text: which necessitated me to transcribe the whole. And when my hand was in, I new made some part of it, and added many new observations of my own, which I have lately made with some very good long glasses, I have in my hands; one of Campani's grinding; and others of Englifh work, which exceed it; but efpecially one of Mr. Huygens's of about 126 feet, which few for goodnefs do furpafs.

Of thefe obfervations the reader fhould have met with many more (and I believe fome of my ingenious friends do expect more) but that I lay under two inconveniences. One the want of an open free horizon, my habitation being furrounded much with trees. The other, and indeed the chief, the want of a long pole of 100 or more feet, to raife my long glafs to fuch an height as to fee the heavenly bodies above the thick vapours; which much obfcure all objects near the horizon, efpecially when viewed with long and good glaffes. But as I have been at confiderable expences already about thefe matters, and this I am informed would amount to 80 or 90l. I thought it too great a burthen for me to bear.

And, therefore, if I have not fufficiently anfwered the expectations of fome of my learned and ingenious friends, I hope they will excufe me, and I believe it to be more my calamity than fault that I have done no more: efpecially among fuch planets as have advantageoufly prefented themfelves, as Saturn particularly hath, whofe five or more fatellites it may be expected

I have

I have feen; but I could never reach but three of them, and they only, when there were but few vapours. And as for the fpots in Mars and Venus, and their motion round their own axis, I confefs I have not yet had good views of thofe planets, fince I have had my furniture of glaffes, by reafon of the too great diftance of Mars from the earth, and the proximity of Venus to the Sun; and of late the cloudy weather, and the fmall altitude which Venus hath above the horizon. But if I can obtain a fufficient apparatus, and God is pleafed to grant me life, health, and leifure, I hope to compenfate for my defects.

But, however, what is here wanting in my own, is fufficiently made up from the obfervations of others, of which the learned world hath good ftore, fince the invention of the telefcope; which as it hath made ample difcoveries of the works of God, fo hath laid open a new, and a far more grand and noble fcene of thofe works, than the world before dreamt of, and afforded us a far more rational fyftem of the heavens and the univerfe, than was before entertained.

And forafmuch as I have frequent occafions in my following book to fpeak of, and according to this and fome of the other fyftems, it is neceffary I fhould by way of preface, give fome account of them to enable fuch perfons to read my book as are unacquainted with aftronomical matters.

Among all the various ſyſtems, I need take notice only of three, the Ptolemaic, the Copernican and the new ſyſtem. Of each of which in their order.

OF THE PTOLEMAIC SYSTEM.

In the Ptolemaic ſyſtem the earth and waters are ſuppoſed to be in the centre of the univerſe; next to which is the element of air, and next above that is the element of fire; next that, the orb of Mercury, then that of Venus, then that of the Sun; and above the Sun's orb, thoſe of Mars, Jupiter, and Saturn; and above them all the firmament, or orb of the fixt ſtars; then the cryſtalline orbs; and laſtly the *cœlum empyreum*, or heaven of heavens. All theſe maſſy orbs, and vaſt bodies borne by them, are in this ſyſtem, ſuppoſed to move round the terraqueous globe once in 24 hours; and beſides that, in ſome other certain periodical times. For the effecting of which motions, they were forced to contrive ſuch circles as they called eccentrics and epicycles, croſſing and interfering with one another; which I could not repreſent in ſo narrow a compaſs as Fig. 1. is, that is a ſcheme of this Ptolemaic ſyſtem; which is univerſally maintained by the Peripatetic philoſophers.

OF

OF THE COPERNICAN SYSTEM.

THE next ſyſtem is the Pythagorean or Copernican, being invented as ſome imagine by Pythagoras himſelf. But Diogenes Laertius [t] expreſsly ſaith, that Pythagoras's opinion was, That the world was round, containing the earth in the midſt of it. And by Pliny's account of [u] Pythagoras, his diſtances, and orders of the planets, this ſeems to have been his opinion. But the ſame Laertius [w] affirms Philolaus, the Pythagorean, τὴν Γῆν κινέισθαι κατα κυκλον, πρῶτον ειπεῖν ἐι δ'ε, Ἱκεταν Συρακουσιον φασιν to have been the firſt that ſaid the earth was moved in a circle; but ſome ſay Hicetas the Syracuſian. So Plutarch in his life of Numa, ſpeaking of Numa's building the temple of Veſta, ſaith, he built it round, and that a continual fire was kept therein, in imitation of the figure of the earth, or rather of the whole world itſelf, the middle of which the Pythagoreans (not Pythagoras) take to be the ſeat of fire.

This ſyſtem (whoever was the inventor of it) Copernicus, a canon of Tourain, reſtored about the beginning of the 15th century, and was followed therein by many conſiderable men, as Rheticus, Mœſtlinus, Kepler, Rothman, Bullialdus, Lanſberge, Herigonius, Schickard,

[t] b. viii. in Pythagora.
[u] Nat. Hiſt. lib. ii. c. 21, 22.
[w] Ibid. in Philolao.

Gaſſendus, Galilæo, and others. The laſt of which (by the ill-will and inſtigation of Pope Urban III. as it is ſuppoſed) had the misfortune to fall under the cenſure of, and to have his Copernican tenets condemned by the inquiſition, and was forced to abjure them. The particulars of which, if the reader hath a mind to ſee, he may find them in Riccioli's Almageſt.[1]

According to this ſyſtem, the ſun is ſuppoſed to be in the centre, and the heavens and earth to revolve round about him, according to their ſeveral periods: firſt Mercury in near 88 days; then Venus in ſomewhat above 224 days; then the earth with its ſatellite the Moon, in 365$\frac{1}{4}$ days; then Mars in about 687 days; then Jupiter with his four moons in about 4333 days; and laſtly, Saturn in ſomewhat above 10759 days, with his five or more moons revolving about him. And beyond, or above all theſe, is the firmament, or the region of the fixt ſtars, which are all ſuppoſed to be at equal diſtances from their centre the ſun.

This is the Copernican ſyſtem, which I have given a ſcheme of in Fig. 2. And ſo far as this ſyſtem relates to the motion of the earth, and the ſun reſting in the centre, I prefer it to the

[1] Lib. ix. Sect. 4. Chap. 40.

Ptolemaic

Ptolemaic hypothesis on these five following accounts:

1. Because it is far more agreeable to nature, which never goes a round-about way, but always acts by the most compendious, easy, and simple methods. And in the Copernican way, that is performed by one, or a few easy revolutions, which, in the other way, is made the work of the whole heavens, and of many strange and unnatural orbs. Thus the diurnal motion is accounted for, by one revolution of the earth, which all the whole heavens are called in for, in the other way; so for the periodical motions of the planets, their stations, retrogradations, and direct motions, they are all accounted for by one easy, single motion round the sun; for which, in the Ptolemaic way, they are forced to invent divers strange, unnatural, interfering eccentrics and epicycles. An hypothesis so bungling and monstrous, as gave occasion to a certain king to say, if he had been of God's council, when he made the heavens, he could have taught him how to have mended his work.

2. As the Copernican is far more easy and agreeable to nature than the Ptolemaic system, so it is far more complete, and answerable to the various phænomena of the planets; several of

which the Ptolemaic hypothesis either very aukwardly solves, or doth not at all come up to. I might instance here in divers particulars relating to Venus and Mercury, as why the earth is never between them and the sun, which the Ptolemaic system gives no tolerable account of, and but poor accounts of other of their phænomena, as also of those of the moon and the other planets. I might shew also how incoherent and improper the motions assigned to the heavenly bodies are in the Ptolemaic way, as that the moon should move round once in a month, the other planets in such and such periods as are assigned to them; the firmament or fixt stars, in 25 or 26000 years; the sphere beyond that in 1700 years; the tenth sphere in 3400 years; and the outermost of all, the *primum mobile*, which moves all the rest, in only 24 hours. Which are motions so unproportional, and disagreeable, that are sufficient to subvert the whole hypothesis. But it would be endless to enter into a detail of such incoherences and improprieties as the Ptolemaic system abounds with.

3. The prodigious and inconceivable rapidity assigned by the Ptolemaic to the heavens, is by the Copernican scheme taken off, and a far more easy and tolerable motion substituted in its room. For is it not a far more easy motion for the earth

to revolve round its own axis in 24 hours, than for so great a number of far more massy, and far distant globes, to revolve round the earth in the same space of time? If the maintainers of the Ptolemaic system do object against the motion of the earth, that it would make us dizzy, and shatter our globe to pieces, what a precipitant, how terrible a rapidity must that of the heavens be? What a velocity must the sun have to run its course, at the distance of 21 or 22 semidiameters of the earth? What a velocity must that of the fixt stars, especially that of the *primum mobile* be, at far greater distances than the sun is?

4. It is an incontestible argument of the sun being the centre of the planets about him, and not the earth; that their motions and distances respect the sun, and not the earth. For with regard to the sun, the primary planets have a very due motion, in proportion to their several distances; that is, their motions round the sun, are in sesquiplicate proportion to their distances from him; but this proportion doth not hold at all with relation to the earth. But as for the secondary planets, round Saturn, Jupiter, and the earth, it is very certain that they have the same respect to their primaries, as these primaries have to the sun; that is, the squares of their revolutions

revolutions are as the cubes of their diſtances; And as it is very certain and viſible, that the ſecondary planets reſpect their primaries as their centres, and move round them, ſo it is in ſome meaſure (one would think) no leſs certain, and beyond doubt, that all the primary planets which have the ſelf ſame reſpect to, and motion with regard to the ſun, as thoſe ſecondaries have to their primaries, that thoſe primaries, I ſay, do move round him as their centre, and not about the earth, to whom they have no ſuch reſpect.

5. The laſt argument I ſhall allege for my preference of the Copernican to the Ptolemaic ſyſtem is from the great parity and congruity obſervable among all the works of the creation; which have a manifeſt harmony, and great agreement with one another.

Thus in our preſent caſe, it is manifeſt to our ſight, that every globe we have any good view of, hath ſuch like motions as thoſe are which we aſcribe to the earth. The ſun, indeed, being in the centre, is as it were fixed there, and hath no periodical motion: but yet the other motion round its own axis, we can manifeſtly diſcern. And as for all the planets which move round about the ſun, they have, as far as it is poſſible for

for us to see them, such motions as those we ascribe to the earth, namely, a diurnal rotation round their own axis, and a periodical revolution round the sun. And if this be manifest in the other planets, what should hinder its being so in our own? Why should ours be singular? Why not be supposed to be moved as well as the rest, when it is very certain that either it hath those motions, or the heavens have so; and it is far more natural and easy for the earth to perform them, than for the heavens, as hath been already shewn.

Thus having shewn how far more probable the Copernican system is than the Ptolemaic, so far as it relates to the motions of the heavens and earth, and the sun being in the centre, it remains (before I proceed to the third and last system) that I should answer some objections alleged against this system, partly from scripture, and partly from philosophy and sight.

The objections from scripture are such as seem to assert the immobility and rest of the earth, and the motion of the sun and heavenly bodies.

The texts that are brought to prove the immobility and rest of the Earth, 1 are Chron. xvi.

xvi. 30. "The world ſhall be ſtable, that it be not moved. The ſame is ſaid, Pſal. xciii. 1. "The world alſo is eſtabliſhed, that it cannot be "moved." And ſo the ſame again Pſal. xcvi. 10. In Pſal. civ. 5. God is ſaid "To lay "the foundations of the Earth, that it ſhould "not be moved for ever." And laſtly, Solomon, Eccleſ. 1. 4. aſſerts that "The earth "abideth for ever. Like to which is that of the Pſalmiſt, Pſal. cxix. 90. "Thou haſt eſtab-"liſhed the Earth, and it abideth." Theſe are the principal texts which ſeem to aſſert the immobility and ſtability of the Earth.

The principal texts which mention the motion of the Sun and heavenly bodies, are ſuch as aſcribe riſing, ſetting, or ſtanding ſtill to them. Thus Gen. xix. 23. "The Sun was riſen "upon the Earth, when Lot entered Zoar." And Gen. xv. 17. "When the Sun went down, "and it was dark, a ſmoaking furnace, &c." So Eccleſ. i. 5. "The Sun ariſeth, and the "Sun goeth down, and haſteth to the place were "he aroſe." So Pſal. xix. 5. 6. The ſun is ſaid "to come out of his chamber like a bride-"groom, and to rejoice as a ſtrong man to run "a race. That his going forth is from the end of "the Heaven, and his circuit unto the ends of "it." Purſuant to which expreſſions of the Sun's

Sun's moving, it is ſaid alſo to ſtand ſtill, and to go backwards. Thus Joſh. x. 12, 13. "Sun, "ſtand thou ſtill upon Gibeon, and thou Moon, "in the valley of Ajalon. And the Sun ſtood "ſtill, and the Moon ſtayed. So the Sun ſtood "ſtill, in the midſt of Heaven, and haſted not "to go down about a whole day." And in 2 Kings xx. 10. and Iſai. xxxviii. 8. the Sun is ſaid to have returned ten degrees backward in one of the places, and its ſhadow to have done ſo in the other.

Theſe are the chief texts of ſcripture, which ſeem to lie againſt the Copernican hypotheſis, in anſwer to which, this may be ſaid in general to them all: that ſince the deſign of the holy writings is not to inſtruct men in philoſophical, but divine matters, therefore it is not neceſſary to reſtrain the ſenſe of thoſe texts to the ſtrict propriety of the words, but take them to be ſpoken according to the appearance of things and the vulgar notions and opinions which men have of them, not according to their reality, or philoſophical verity. Thus in divers other inſtances the holy ſcriptures ſpeak, and thus even philoſophers themſelves ſpeak. Yea, the Copernicans themſelves, altho' they profeſſedly own, and defend the contrary; yet in vulgar ſpeaking in our preſent caſe, ſay, The ſun riſeth, ſetteth and moveth, &c. making that to be the act of the Sun in vulgar discourse, which they contend to be in reality performed by the Earth. And if philosophers and others did not thus express themselves according to the appearance of things and men's vulgar apprehensions of them, it would need a comment, and they must explain themselves every time they speak, in order to their being understood.

Having given this general answer, I shall next consider the particular texts themselves; and see whether they necessarily infer what they are brought for the proof of.

And in the first place, as for the texts brought to prove the immobility of the Earth, it is manifest that the stability of the world, mentioned in the three first texts, doth not relate to the earth's motion, either annual, or diurnal, but to the condition, state, and order of the world inhabiting the Earth, particularly the peace and prosperity thereof. One of our own latest, and most learned commentators, the late bishop Patrick [y], understands the gospel-state to be meant in the first and third of the texts. And his paraphrase

[y] See his commentary on Chron. and his paraphrase on Psalms.

phrase on that in Psal. xciii. 1. is, "he who made "the world, will support that excellent order "wherein we are settled; so that it shall not be "in the power of man to disturb what he hath "established."

As for what is said in Psal. civ. 5. it is manifest that the psalmist is there celebrating the works of creation, and that there was as fair an occasion of speaking of the Earth's rest, in relation to its own motions, as any where. But yet even here also the security and permanency of its state is the thing aimed at. The last most learned commentator thus paraphrases on the place: [z] "Who hath settled the massy globe of the Earth, even in the liquid air, upon such firm foundations, that none of those storms and tempests which beat upon it from without, nor any commotions from within, can ever stir it out of the place he hath fixed for it."

As for the two remaining places in Eccles. and Psal. cxix. it is plain enough that their design is to shew the vanity and instability of the things of this world, that they are all more fleeting and uncertain than other matters, even than the Earth itself, on which they have their residence.

[z] Bishop Patrick's paraph. on Psal. civ. 5.

In

In Ecclef. the wife man (who had undertaken to prove all things here below to be vanity) begins with the ftate of man himfelf, and fhews that to be more fickle and tranfitory than the Earth, on which the various generations of men live, and to which their bodies do all return again. The generations of men pafs away; "but the Earth "abideth for ever," in the fame unalterable condition, without fuch going and coming, as that of the generations of men have.

In Pfal. cxix. 90. the Pfalmift celebrates God's faithfulnefs to all the various and fucceeding generations of the world, which he fhews to be as conftant and as unalterable as the Earth itfelf, which God hath fo eftablifhed, that it abideth through all the feveral generations of men, when they at the fame time are fleeting and changing.

Thus it appears that all thofe feveral texts which affert the ftability of the world, or Earth, prove nothing againft the Earth's motion, in a philofophical fenfe; only exprefs fome moral, theological truths.

And fo the fame may be faid of thofe other places of fcripture, which mention the motion of of the Sun and other heavenly bodies, that ſay, they riſe, ſet, and perform the motion which the Copernicans aſcribe to the Earth. If we ſhould take theſe expreſſions in a philoſophical, ſtrict, literal ſenſe, and not as vulgar expreſſions ariſing from the appearance of things; we ſhall find that very odd and unreaſonable concluſions may as well be collected from thoſe ſcriptures as the Sun's motion: as that the Sun hath annual life, motion, and deſire, being ſaid to act theſe things itſelf, to riſe, to ſet, yea to haſte to the place of his riſing, or, as the Hebrew hath it, to pant after, or eagerly to deſire it [a]. So in Pſal. xix. the elegant pſalmiſt giving a poetical deſcription of this noble and admirable work of God, the Sun, ſaith, " God hath, in the Heavens, made a tabernacle for him;" as if the Sun had an houſe, a reſting-place provided for him; from which he comes daily forth with beauty and luſtre, as reſplendent as that of a bridegroom; and with the ſame ardency, joy, and diligence runs his courſe, as a champion doth his race. And laſtly his going forth is ſaid to be from the end of the Heaven, and his circuit to reach to the ends thereof; as though the Heavens had two extremities, or was, as the ancients fancied the

[a] שאף Anhelavit, inhiavit, vid. Buxtorf. Lexicon.

 Earth

Earth to be, a long large plane, bounded by the ocean, under which they imagined the Sun betook himſelf, and was thence ſaid *tingere ſe Oceano*, to dip himſelf in the ocean when he ſet.

And, as in theſe places of ſcripture the Sun is ſaid to move; ſo in the other places he is ſaid to ſtand ſtill, and to go backward. But we ſhall find, that very abſurd concluſions would follow the taking thoſe texts in a ſtrict literal ſenſe. For in Joſhua, the Sun is ordered to ſtand ſtill upon Gibeon, and the Moon in the valley of Ajalon. But it would be very abſurd to take this in a literal ſenſe, and imagine thoſe two great luminaries were confined to thoſe two places, otherwiſe than in appearance to the victorious Iſraelites. And if ſo conſiderable a part of the tranſaction be ſpoken according to its appearance, why not the whole? Why might not this ſtation as well be an arreſt of the Earth's motion as that of the Heavens, if the whole miracle was not (as ſome not improbably think) effected by means of ſome preternatural refractions or extraordinary meteors, &c.

And ſo for the receſs of the Sun, or its ſhadow in Hezekiah's caſe, that which in appearance ſeemed to be the action of the Sun is by divers learned

learned men thought to have been the effect of ſuch like extraordinary refractions and meteors, as I mentioned in the laſt caſe: or if it was a real receſs, why not of the Earth, rather than the Sun and whole Heavens?

Thus having anſwered the particular texts, it doth not appear that the ſcriptures oppoſe the Copernican ſyſtem, but that thoſe paſſages which ſeem to do ſo, are ſpoken more according as things appear, than as really they are. For as St. Hieron ſaith, [b] *Conſuetudinis ſcripturarum eſt*—It is the cuſtom of the ſcriptures, for the hiſtorian ſo to relate the opinion men had of many matters, as at that time theſe matters were by all people taken to be. And in another place [c], "There are many things in the holy ſcriptures, which are ſpoken according to the opinion of the time in which they were done, and not according to their reality." And this is no other than what is very reaſonable, and ſuitable to the end and deſign of the holy ſcriptures, which, as I have ſaid, is rather to inſtruct men in divine and moral doctrines, than philoſophical truths. And agreeably

[b] Hieron. in Joſh. x.

[c] In Jerem. xxviii.

hereto, St. Auguſtine anſwers this very doubt concerning the motion of the Heavens. [d] "Some of the brethren (ſaith he) move a queſtion, whether the Heavens ſtand ſtill or are moved; becauſe, ſay they, if they are moved, how is it a firmament? and if they ſtand ſtill, how do the ſtars, which are believed to be fixt in them, revolve from eaſt to weſt, the northern ſtars deſcribing leſſer circles near the pole?" —To which, ſaith he, I anſwer, "That theſe things do greatly require ſeveral ſubtle and laborious reaſons, to diſcover truly whether the matter be ſo, or not ſo. For the entering upon, and diſcuſſing of which, I have neither time, nor is it fit it ſhould be done to ſuch as we deſire to inſtruct in the way of ſalvation, for the neceſſary benefit of the holy church."

Having thus anſwered the objections from ſcripture, I ſhall in the laſt place conſider thoſe brought from ſenſe and philoſophy.

The objections from ſenſe is, That we ſee the heavenly bodies actually to move, and therefore ought to believe they do ſo. But there is no

[d] Auguſt. de Geneſi ad Literam, l. ii. 10.

weight

weight in this, becaufe whether we ourfelves, or the object moveth, it amounts to the fame. As is manifeft to any one carried in a boat or chariot; the progreffive motion of which produceth the appearance of a regreffive motion in the unmoved objects we look upon; according to Virgil's defcription of Æneas and his company's leaving their port.

Provehimur portu, terræque urbefque recedunt [e].

i. e. "Both lands and towns receded when we left our port." As for the reafon hereof, I fhall refer to the opticians, particularly the famous Kepler, who in his Optices Aftronom. hath defignedly handled this point.

The objections from philofophy are too numerous to be diftinctly anfwered, efpecially fuch as feem very frivolous; particularly thofe grounded on a fuppofition of the verity of the Ariftotelian philofophy; as the immutability and incorruptibility of the Heavens, &c. For anfwers to which I fhall refer the reader to Galilæo's Syftema Mundi: but for fuch objections as feem to have fome reafon in them, they are chiefly thefe, That

[e] Æneid. l. iii. car. 72.

if the Earth be moved from W. to E. a bullet ſhot weſtward would have a farther range, than one ſhot Eaſtward; or if ſhot N. or S. it would miſs the mark; or if perpendicularly upright, it would drop to the weſtward of the gun. That a weight dropped from the top of a tower would not fall down juſt at the bottom of the tower, as we ſee it doth. That birds flying towards the E. would be hindered in their flight, but forwarded in flying the contrary way; with much more to the ſame purpoſe. But not to enter into a detail of anſwers that might be given to the laws of motion, and the rules of mechanics and mathematicks, I ſhall only make uſe of the moſt ingenious Galilæo's plain experiment, which anſwereth all, or moſt of the objections. [f] "Shut, ſaith he, yourſelf up with your friend in the great cabin of a ſhip, together with a parcel of gnats and flies, and other little winged creatures. Procure alſo a great tub of water, and put fiſhes therein. Hang alſo a bottle of water up, to empty itſelf drop by drop into another ſuch bottle placed underneath, with a narrow neck. Whilſt the ſhip lies ſtill, diligently obſerve how thoſe little winged creatures fly with the like ſwiftneſs towards every part of the cabin; how

[f] Syſtem. Mund. Dial. 2.

the

the fishes swim indifferently towards all sides; and how the descending drops all fall into the bottle underneath. And if you throw any thing to your friend, you need use no more force one way than another, provided the distances be equal. And if you leap, you will reach as far one way as the other. Having observed these particulars whilst the ship lies still, make the ship to sail with what velocity you please; and so long as the motion is uniform, not fluctuating this way and that way, you shall not perceive there is any alteration in the aforesaid effects; neither can you from them conclude, whether the ship moveth or standeth still. But in leaping you shall reach as far on the floor as you did before; nor by reason of the ship's motion, shall you make a longer leap towards the poop than the prow; notwithstanding that whilst you were up in the air, the floor under your feet had run the contrary way to your leap. And if you cast any thing to your companion, you need use no more strength to make it reach him, if he should be towards the prow; and you towards the poop, than if you stood in a contrary position. The drops shall all fall into the lower bottle, and not one towards the poop, although the ship shall have run many feet, whilst the drop was in the air. The fishes in the water shall have no more trouble in ſwimming towards the forepart of the tub, than towards the hinder part, but ſhall make towards the bait with equal ſwiftneſs, on any ſide of the tub. And laſtly, the gnats and flies ſhall continue their flight indifferently towards all parts, and never be driven together towards the ſide of the cabin next the prow, as if wearied with following the ſwift motion of the ſhip. And if by burning a few grains of incenſe, you make a little ſmoak, you ſhall perceive it to aſcend on high, and hang like a cloud, moving indifferently this way and that, without any inclination to one ſide more than another. The cauſe of which coreſpondence of the effects, is, that the ſhip's motion is common to all things contained in it, and to the air alſo: I mean when thoſe things are ſhut up in the cabin: but when they are above deck in the open air, and not obliged to follow the ſhip's courſe, differences more or leſs may ariſe among the forenamed effects."

Thus Galilæo by this one obſervation hath anſwered the moſt conſiderable objections deduced from philoſophy againſt the motion of the earth. And thus much ſhall ſuffice for the explanation and proof of the Copernican ſyſtem; eſpecially that part of it relating to the Solar ſyſtem.

ſyſtem. Which things I have more largely than ordinary inſiſted on, for the ſatisfaction of many that I am ſenſible doubt of them, and particularly ſome of my friends, (and thoſe not unlearned too) who may be apt to read my following book with prejudice, whereſoever I favour the Copernican notions.

OF THE NEW SYSTEM.

AND now I paſs from the ſecond ſyſtem to the third, which is called the New Syſtem; which extends the univerſe to a far more immenſe compaſs, than any of the other ſyſtems do, even to an indefinite ſpace; and repleniſhes it with a far more grand retinue than ever was before aſcribed unto it.

This new ſyſtem is the ſame with the Copernican, as to the ſyſtem of the ſun and its planets, as may be ſeen by the ſcheme of it in Fig. 3. But then whereas the Copernican hypotheſis ſuppoſeth the firmament of the fixt ſtars to be the bounds of the univerſe, and to be placed at equal diſtances from its centre the ſun, the new ſyſtem ſuppoſeth there are many other ſyſtems of ſuns and planets, besides that in which we have our residence: namely, that every fixt star is a sun, and encompassed with a system of planets, both primary and secondary, as well as ours.

These several systems of the fixt stars, as they are at a great and sufficient distance from the sun and us; so they are imagined to be at as due and regular distances from one another. By which means it is, that those multitudes of fixt stars appear to us of different magnitudes, the nearest to us large; those farther and farther less and less.

Of those systems of the fixt stars I have given a rude representation in Fig. 3. together with that of the sun; which may serve to give an unskilful reader some conception of the state of the universe; although there be but little likeness in it, for want of room to lay out all the several systems in due proportion; which is necessary to a true representation of the matter.

In this 3d Fig. the fixt stars with their systems (represented by little circles about those stars, which circles signify the orbits of their respective planets) are placed without the limits of the Solar system, and the Solar system is set in the centre of the universe, and figured as a more grand

grand and magnificent part thereof. And ſo it may be looked upon by us, by reaſon of its proximity and relation to us. But whether it be really ſo, whether it be in the centre of the univerſe, and whether among all the noble train of fixt ſtars, there be no ſyſtem exceeding ours in its magnificent retinue of planets, both primary and ſecondary, and other admirable contrivances, is a difficulty as out of the reach of our glaſſes, ſo conſequently above our ability to fathom, although not at all improbable. But be the various ſyſtems of the univerſe as they will as to their dignity, it is ſufficient that in all probability there are many of them, even as many as there are fixt ſtars, which are without number.

This ſyſtem of the univerſe, as it is phyſically demonſtrable, ſo is what, for the moſt part, I have followed in the enſuing book, but not ſo rigorouſly and obſtinately, as utterly to exclude or oppugn any other ſyſtem; becauſe as the works of God are truly great, and ſufficiently manifeſt their excellence and magnificence in any ſyſtem; ſo I was willing to ſhew the ſame in ſuch ſyſtems as I had occaſion to ſpeak of them; becauſe I would not offend, and conſequently not bar the force of my arguments upon

ſuch

ſuch readers, as might happen to be wedded to the Ariſtotelian principles, or prejudiced to the Ptolemaic, or any other ſyſtem: nor that I had myſelf any doubts about this new ſyſtem, but think it to be far the more rational and probable of any, for theſe reaſons:

1. Becauſe it is far the moſt magnificent of any; and worthy of an infinite Creator: whoſe power and wiſdom as they are without bounds and meaſure, ſo may in all probability exert themſelves in the creation of many ſyſtems, as well as one. And as myriads of ſyſtems are more for the glory of God, and more demonſtrate his attributes than one, ſo it is no leſs probable than poſſible, there may be many beſides this which we have the privilege of living in. But it is very highly probable the matter is ſo, by reaſon

2. We ſee it really ſo, as far as it is poſſible it can be diſcerned by us, at ſuch immenſe diſtances as thoſe ſyſtems of the fixt ſtars are from us. Our glaſſes are indeed too weak ſo to reach thoſe ſyſtems, as to give us any aſſurance of our ſeeing the planets themſelves, that encompaſs any of the fixt ſtars. We cannot ſay we ſee them actually moving round their reſpective ſuns or ſtars.

ſtars. But this we can diſcern, viz. That the fixt ſtars have the nature of ſuns, as I have made probable in Book ii. Chap. 2. As alſo that there are ſome things very like unto planets, which ſometimes appear and diſappear in the regions of the fixt ſtars; as I have ſhewn in my diſcourſe of new ſtars, Book ii, Chap. 3.

But beſides what I have ſaid there, I have this farther to add from ſome late obſervations I have made ſince my writing that part of my book; and that is, that the Galaxy being well known to be the fertile place of new ſtars, the region in which they commonly appear, I am much inclined to be of opinion, that the whiteneſs there is not cauſed by the bare light of the great number of fixt ſtars in that place, as hath commonly been thought, but partly by their light, and partly (if not chiefly) by the reflections of their planets; which ſtop and reflect, intermix and blend the light of their reſpective ſtars or ſuns, and ſo cauſe that whiteneſs the Galaxy preſents us with; which hath rather the colour of the reflected light of our moon, than the primary light of our ſun.

And that there are planets enough for this purpoſe, I ſuſpect, becauſe I have ſome reaſons to imagine that there are many more new ſtars in the

the milky way (all which I take to be a kind of planetary globes) than have ever yet been taken notice of, and that many of thoſe prodigious numbers of teleſcopial ſtars viſible there, are of the numbers of new ſtars or planets, and not of fixt ſtars only. This ſuſpicion I have for ſome time had, but eſpecially lately from my views of the new ſtar that now begins to diſappear in the Swan's neck. Which gave me occaſion to inſpect ſome other parts of that conſtellation, moſt parts of which are well repleniſhed with a numerous train of ſmall ſtars, Amongſt whieh, ſometimes methought more have preſented themſelves through one and the ſame glaſs; and ſometimes I have miſſed ſome I thought I before ſaw; and ſometimes alſo methought I have ſeen them nearer too, and ſometimes farther off thoſe ſtars that did conſtantly preſent themſelves. But as theſe things are to myſelf novel, and what I confeſs I have rather ſuſpicions of, than certainty, I ſhall refer them to the future obſervations of myſelf and others, for their confirmation; eſpecially, becauſe thoſe approximations and receſſes of ſome of the little ſtars I ſpoke of, ſuit not with the obſervations of ſome very eminent aſtronomers.

Theſe

These obſervations, as they will open to us a new, and admirable ſcene of the heavens, (if it be as I imagine) ſo I earneſtly recommended the enquiry into it to ſuch as delight in thoſe matters. For the doing of which, I conceive it may be ſufficient, and the eaſieſt courſe to make the obſervations in ſome one part of the milky-way, as in ſome part of the Swan; as much or a little more than falleth within the compaſs of the teleſcope you make uſe of, which was the way I practiſed, in that part of the heavens in which I obſerved. All the ſtars that fall within this area, an exact map muſt be taken of, which will ſhew when any variations happen. And for taking in the larger area of the heavens, a glaſs of ſix or eight feet is ſufficient, and rather better for the purpoſe than longer glaſſes, which take in leſs, and are more troubleſome in uſing.

Having thus repreſented the ſtate of the univerſe according to the new ſyſtem of it, the uſual queſtion is, what is the uſe of ſo many planets as we ſee about the ſun, and ſo many as are imagined to be about the fixt ſtars. To which the anſwer is, that they are worlds, or places of habitation; which is concluded from their being habitable, and well provided for habitation. This is pretty manifeſt in our ſolar

planets,

planets, from their being opake bodies as our earth is; confifting in all probability of land and waters, hills, and valleys, having atmofpheres about them, moons miniftering unto them, and being enlightened, warmed, and influenced by the fun, whofe yearly vifits they receive for feafons, and frequent returns for days and nights. All which particulars are fully treated of in the following book, and need not therefore to be anticipated here. Only there is one thing, which, for want of fufficient obfervations, I could not fo fully fpeak of as I would; and that is concerning the feas in the moon, in book v. chap. 4. whofe very exiftence Mr. Huygens [g] denies, faying, *Marium vero fimilitudinem illic nullam reperio, &c.* i. e. "In the moon I find no likenefs of feas," although Kepler and moft others are of a different opinion. For thofe vaft plane regions, which are much darker than the mountainous parts, and are commonly taken for feas, and bear the names of oceans; in thofe very places viewed with a long telefcope, I find little round cavities with fhadows falling within them; which cannot agree with the furface of the fea; as alfo thofe very large fields, when carefully viewed, do not prefent us with a fuperficies altogether equal. Wherefore thefe cannot be feas, but are fuch places as confift of a lefs bright matter

[g] Cofmotheorof. p. 114.

than

than that which is in the hilly parts, but in which alſo there are ſome places brighter than others." Thus the moſt ingenious Mr. Huygens, who then proceeds to ſhew that there are neither rivers, clouds, air, or vapours.

But that there are ſeas, or great collections of water, and conſequently rivers, clouds, air, and vapours in the moon, I ſhall make out from ſome of my own views and obſervations; many of which were made with Mr. Huygens's own long glaſs before mentioned: through which, and all other long glaſſes, inſtead of imagining the lunar ſpots to be unlike ſeas, I have always thought them to look more like ſeas, than through ſhort glaſſes.

It is true indeed that in thoſe ſpots we take to be the ſeas, there are ſuch cavities as Mr. Huygens ſpeak of, or rather mountains with ſhaded cavities in them, as alſo ſome parts leſs dark than others. Thus in the ſoutherly parts of the Lunar Euxine and Mediterranean, in the Sinus Sirbonis, the Egyptian, and divers other ſeas, there are ſeveral ſuch parts that appear more luminous than others, ſome having the appearance of rocks and iſlands, ſome of large ſhallows, particularly towards the ſhores, and eſ-

 pecially

pecially in the ſeas bordering on the continents, ſuch as the great ſouthern continent of the Lunar Ægypt and Palæſtine. But this is no concluſive argument of thoſe parts not being ſeas; becauſe they may be ſeas having many iſlands and ſhallows in them. But then in other parts, and even in ſome parts of theſe laſt named, the ſpots appear darker, and with but few of thoſe eminencies or iſlands, thoſe brighter or ſhallow parts. Thus the northerly Euxine and Mediterranean, the Palus Mæotis, and many other of thoſe lunar ſeas; few of thoſe parts that have the aſpect of iſlands or ſhallows are to be diſcerned in them, only one here, and another there, at conſiderable diſtances from one another.

And in this very manner I doubt not our terraqueous globe would appear, if viewed at the moon, or at ſome miles aloft. We ſhould there perceive our deep oceans would be of a darker colour, like the darker ſpots of the moon; and the ſingle iſles of St. Helena and Aſcenſion, and the more numerous ones of Ladrones, Canaries, Azores, &c. to have the ſame appearance that the few ſcattered iſlands have in the deeper lunar ſeas: and our ſhallow ſeas with the numerous rocks and iſlands diſperſed about them, eſpecially ly towards the continents, would look as thoſe in the moon do.

That a reader unacquainted with the geography of the moon, may apprehend what I have ſaid here and elſewhere, concerning the parts and appearances of the moon, I have repreſented them in Fig. 10. and 11. In Fig. 10. the face of the full moon is repreſented, its bright and dark parts with moſt of the names given them by Hevelius, whoſe Lunar Geography is juſtly the moſt followed. In Fig. 11. I have repreſented the appearance of the moon's edge on this laſt Nov. 4, 1714, ſoon after the quadrature, for the explication of what is ſaid concerning the evenneſs of the ſurface of the lunar ſpots in book V. chap. 4. It may be there obſerved, that the ſurfaces of all the ſeas appear ſtrait and level, only the top of here and there a rock or iſland preſents itſelf at a ſmall diſtance. Thus the ſurface of the Hyperborean ſea between *a* and *b* appears even and level, although through a teleſcope that ſea looks but like a great lake or marſh. So do the parts of the Mediterranean about *d*, from *h*, to *i*, except when they are interrupted by rocks or land, as they are at *h*, *g*, *b*, and *c*. At the laſt of which places, begins a ridge of hills encompaſſing the northern part of the Mediterranean, which makes a pretty ſhew in the teleſcope.

And now conſidering how accompliſhed the moon, and all the other planets are for habitation, how ſolemn an apparatus is in them for this ſervice; and conſidering alſo that theſe accoutrements relate to their reſpective planets only, and in all probability are of little or no uſe to our earth; with great reaſon therefore the maintainers of the new ſyſtem conclude thoſe planets, yea all the planets of the ſun and of the fixt ſtars alſo, to be habitable worlds; places, as accommodated for habitation, ſo ſtocked with proper inhabitants.

But now the next queſtion commonly put is, What creatures are they inhabited with? But this is a difficulty not to be reſolved without a revelation, or far better inſtruments than the world hath hitherto been acquainted with. But if the reader ſhould have a mind to amuſe himſelf with probable gueſſes about the furniture of the planets of our ſolar ſyſtem, what countries it is probable are there, what vegetables are produced, what minerals and metals are afforded, what animals live there, what parts, faculties, and endowments they have, with much more to the

the ſame purpoſe; he may find a pleaſant entertainment enough in the great Mr. Chriſtian Huygens's Coſmotheoros, and ſome other authors that have written on the ſubject. To which I ſhall refer him, rather than give either him or myſelf any farther trouble about theſe matters, which are merely conjectural.

Thus having, for the ſake of the unſkilful reader, given an account of the three ſyſtems principally concerned in the following book, and having alſo, for the ſake of the doubting reader, inſiſted more largely than ordinary upon the two laſt of thoſe ſyſtems, little remaineth for the putting an end to this long preface, but to make my excuſe (if it needs any) for aſſigning the diameters and diſtances of the heavenly bodies in Engliſh miles, rather than other larger meaſures, which would perhaps have come nearer the truth. But this was alſo for the ſake of ſuch as are not very converſant in aſtronomical matters and dimenſions: who can better underſtand you, when you ſay, it is ſo many miles, than ſo many degrees, minutes, or ſeconds, or ſemidiameters of the earth, or the other planets.

And now for a concluſion, I ſhall only intreat all my readers to join with me in their earneſt prayers, that as this work is designed for the good of mankind, particularly for the conviction of infidels and irreligious, for the promotion of the fear and honour of God, and the cultivating of true religion, so it may have its desired effect.

W. DERHAM.

A

A SURVEY OF THE HEAVENS.

INTRODUCTION.

THE psalmist saith, [h] "The heavens declare "the glory of God; and the firmament "sheweth," publickly declareth, telleth forth, or preacheth his handy work, as the Hebrew word signifies: [i] that "day unto day uttereth "speech, and night unto night, sheweth, or "tells forth, knowledge." Which language of

[h] Psalm xix. 1, 2, 3.

[i] נָגַד significat aliquid verbis efferre, coram nuntiare, annunciare, Conrad. Kircher. Concord. col. 216. vol. ii. It is derived from נֶגֶד Coram, Ante.

the heavens is so plain, and their characters so legible, that all, even the most barbarous nations, that have no skill either in languages or letters, are able to understand and read what they proclaim. "There is no speech nor "language where their voice is not heard: their "line is gone out through all the earth, and "their words to the end of the world.

That this observation of the psalmist is agreeable to experience, is manifest from the deductions which all nations have made from God's works, particularly from those of the heavens; namely, that there is a God; and that such as have pretended to atheism, and have deduced God's works from chance, &c. are singular and monstrous in their opinions. Thus saith Ælian,[k] "There never was any barbarian that contemned the Deity, nor called in question whether "there be any gods or no; or whether they "take care of human affairs; No man, neither "Indian, nor Celt, nor Egyptian, ever entertained any such thought as Eumerus the Messenian, "or Dionysius the Phrygian, or Hippo, or "Diagoras, or Socias, or Epicurus." So one of Plato's arguments for the proof of a God, is[l]

[k] De var. Hist. l. ii. c. 31.

[l] De Legibus, l. x.

"The

"The unanimous consént of all, both Greeks "and Barbarians, who confess there are gods." And Plutarch, [m] agreeable to what our psalmist affirms, tells us whence they collected this knowledge of a Deity. "Men," saith he, "began "to acknowledge a God, when they saw the "stars maintain so great a harmony, and the days "and nights through all the year, both in sum-"mer and winter, to observe their stated risings "and settings." And to pass over a great deal of this kind, that I could cite from divers heathen authors, "What," saith the Stoic in Tully, [n] "can be so plain and so clear, as when "we behold the heavens, and view the heaven-"ly bodies, that we should conclude there is "some deity of a most excellent mind, by which "these things are governed?—a present and Al-"mighty God. Which he that doubts of, I do "not understand, saith he, why he should not "as well doubt whether there be a sun or not "that shines." And then he goes on to prove that this can be no idle fancy depending on the caprice of man; but a well grounded, substantial opinion,

[m] De placit. Philos. l. i. c. 6.

[n] Quid enim potest esse tam apertum, tamque perspicuum, cum Cælum suspeximus, &c. De Nat. Deor. l. ii. c. 2.

opinion, bearing the teſt of ages, and confirmed by the length of time. "For," ſaith he, "time "wears out the figments of opinions, but con-"firms the judgments of nature; or ſuch notions "as are grounded upon the true judgment and "nature of things. For which reaſon, ſaith he, "both among ourſelves, and in other nations, "the veneration of the gods, and the ſacred-"neſs of religion, augment and improve every "day more and more."

Thus "the heavens declare the glory of God," even to the heathen world; ſo manifeſtly are they the handy-work of God. And that they are his work, will appear by taking a view of theſe ſeven particulars,

1. The magnitude of the heavens.
2. The great number of the heavenly bodies.
3. Their diſtances.
4. Their motions.
5. Their figures.
6. Their gravity.
7. Their light and heat, and the admirable proviſions made for thoſe benefits.

BOOK

BOOK I.

OF THE MAGNITUDE OF THE UNIVERSE, AND THE BODIES THEREIN CONTAINED.

CHAP. I.

THE ANCIENT AND MODERN RECKONINGS COMPARED.

BEFORE the invention of the telescope, the universe was thought to be confined within far more narrow bounds than it is since found to be, the fixt stars being imagined to be all placed in the starry heavens (which they called the firmament) at equal distances from the earth (the centre) like so many golden nails driven in the top of some arched roof, or other circular concave,

concave, encompaſſing our eye. Theſe, although far more narrow bounds, and a more ſcanty reckoning than it ſhould be, yet was ſufficient to ſhew who was the maker of ſuch a ſtupendous arch, and ſo noble a train as is contained therein.

But according to the modern reckoning (which is far the moſt rational, and grounded upon better phænomena) we ſhall find this branch of the creation far more magnificent, and worthy of its infinite Creator, than thoſe former computations made it.

And how grand and magnificent a ſtructure the heavens are, will appear by a diſtinct conſideration of the magnitude of the heavenly bodies themſelves; and of the ſpace in which they are.

CHAP.

CHAP. II.

THE MAGNITUDE OF THE HEAVENLY BODIES.

ALTHOUGH we are not able to give a certain determination of the magnitude of the heavenly bodies by reafon of their vaft diftances, yet enough we know, and are fure of, concerning their immenfe magnitudes, to convince any one that they are the works of God. But to come to particulars.

The meafure by which we ufually gage and compare the heavenly bodies, is our terraqueous globe; of whofe dimenfions and bulk we can make a pretty good eftimate, having tolerably good and accurate obfervations leading us thereto: the particulars of which I have had occafion elfewhere to fpecify [a].

By

[a] ' Phyfico-Theol. B. ii. c. 2. In which place I have made ufe of Mr. Picart's meafure of the earth. But notwithftanding the difference be but fmall, viz. a little above 32 miles in the whole diameter of our globe, yet I fhall make ufe here of our Mr. Norwood's

By these observations it appears that the diameter of this our globe is above 79 hundred miles; that consequently its surface is a good deal above 199 millions of miles, and its solid content or bulk near 265 thousand millions of miles. If therefore we should go no farther from home than our own globe, a mass we here have worthy of an infinite Creator, a work proclaiming that great Being that made it.

But as vast a body as this seems to be, it is much less than many, yea most of the heavenly bodies that are visible to us; except two or three of the planets, which seem to be less than our globe; namely Mars, whose diameter is reckoned to be but 4875 English miles, and the Moon, whose diameter is but 2175 miles; and Mercury, whose diameter is 2748 miles: [p] but yet these vast

wood's and Monf. Cassini's measures, because they agree to almost a niceety, and Mr. Cassini's were made (by the king's command) at greater distances, with the greatest accuracy. And according to these measures, the diameter of the earth is 79677 English miles, its surface 199444201 miles, and its solid content 264856000000 miles.

[p] The number of miles, which I have here and all along assigned to the diameters of the several planets, are the mean numbers between Mr. Flamsteed's in Mr. Whiston's Astronomical Lectures, and Mr. Huygens's in his Syst. Saturn. and Cosmotheor. which (as Mr. Whiston first suggested to me) seems to be nearest the truth.

For

§

vaſt and amazing bodies too! But for the reſt, there is good reaſon to imagine their bulk exceeds that of our terraqueous globe. Thus the two ſuperior planets by far exceed us; Saturn being computed at 93451 miles in diameter, and conſequently at 427318300000000 miles in its bulk; and Jupiter at 120653 miles in diameter, and 920011200000000 miles in bulk. But yet as amazing maſſes as theſe all are, yet they are all far outdone by that ſtupendous globe of fire, the ſun; which as it is the fountain of light and heat to all the planets about it, affording them by his benign rays, and kindly influence the great pleaſures and comforts of life; ſo doth it as far ſurpaſs them in its bulk; its apparent diameter being computed at 822148 Engliſh miles, and its ſolid content at 290971000000000000 miles, ſuppoſing the face we ſee of the ſun to be its true and real globe.

For whereas the rays of light, when intercepted by the edge of a knife or other body, are (as Sir Iſaac Newton obſerves in his Princip. l. i. prop. 96.) are ſomewhat bent, as if attracted from a ſtraight line by that body; and whereas Mr. Flamſteed's meaſures were taken with a micrometer that pinches or claſps the oppoſite edges of a planet which would incurvate the rays one way; and Mr. Huygens's were taken with the interpoſition of a thin tapering plate covering the planet as far as the extremity of its face, which would cauſe an incurvation of the rays the contrary way; therefore Mr. Flamſteed's meaſures are as much too little, as Mr. Huygens's are too large, and conſequently the mean between them probably neareſt the truth.

Thus

Thus ſtupendous are the magnitudes of the globes of this our ſolar ſyſtem: but theſe are not all, nor perhaps the moſt conſiderable bodies of the univerſe. For the fixt ſtars, although in appearance but ſo many golden or flaming ſpots, yet are, with great probability, ſuppoſed to be ſo many ſuns, ſurrounded with their reſpective ſyſtems of planets, as our ſun is, and no leſs in magnitude, if not greater, (ſome of them at leaſt) than our ſun is, but only diminiſhed in appearance by their prodigious diſtances from us.

If now we reflect upon the prodigious maſſes of thoſe many heavenly bodies that preſent themſelves to our view, and many more I ſhall ſhew are unſeen; what a ſurprizing ſcene do the heavens afford us of the great Creator's power! A train of ſuch immenſe bodies, that what leſs than an Almighty hand could firſt find matter ſufficient for, and then compoſe, ſuch magnificent works! But yet what is the magnitude of all theſe bodies to that immenſe ſpace in which they are? Which is the next thing to be conſidered.

CHAP.

CHAP. III.

OF THE IMMENSITY OF THE HEAVENS.

IT is neceſſary that I ſhould give a diſtinct conſideration to the immenſe ſpace poſſeſt by the heavenly bodies, becauſe it was once imagined to be limited by the narrower bounds of the Ptolemaic ſyſtem, by that which they called the 'Απλανὴς, the ſtarry concameration, or firmament of the fixt ſtars, as I have before intimated; but now with far greater probability and reaſon it is extended to an indefinitely larger ſpace, a ſpace ſufficient without all doubt to contain all the noble variety of ſyſtems therein; not only our own of the Sun, but all thoſe others I mentioned of the fixt ſtars alſo. But for the better proof, and more eaſy apprehenſion of the magnitude of this vaſt expanded ſpace, let it be conſidered.

1. That ſome, if not every one of thoſe vaſt globes of the univerſe, hath a motion. This is, in ſome, manifeſt to our ſight, and may eaſily be

concluded of all, from the conſtant ſimilitude and conſent that the works of nature have with one another. But in what manner theſe motions are performed, whether by the motion of the heavenly bodies round the Earth, or by the Earth round its own axis, or any other way, it matters not much how to enquire.

2. It is manifeſt that the Earth is ſet at ſuch a due diſtance from the heavenly bodies, and the heavenly bodies, at ſuch a due diſtance from one another, as to interfere, claſh with, or diſorder one another; nay, ſo great is their diſtance, ſo convenient their ſituation, that they do not ſo much as eclifpe one another, except ſuch planets as are called ſecondary.

3. It is farther manifeſt alſo, that thoſe vaſt bodies are ſo far off, as to appear extremely ſmall to our eye, conſidering their prodigious magnitudes.

Now for the effecting of this, or any of the other matters, it is neceſſary that there be a ſufficient ſpace. And that there is ſuch, and what that ſpace is, we may make a judgment of, by conſidering particulars according to the beſt obſervations we have of theſe things.

And

And to begin neareſt home; the neareſt of the heavenly bodies to us is the Moon, whoſe orb is the leaſt of any of the celeſtial globes, but yet ſhe takes up a ſpace of neat 480 thouſand Engliſh miles in breadth [q], to perform her monthly revolution in. And as for the Earth, if with the moderns we ſuppoſe it, together with its ſatellite the Moon, to revolve round the Sun; or, which amounts to the ſame thing, if the Sun revolves round the Earth, this Magnus Orbis, as it is uſually called, is a ſpace of above 540 millions of miles in circumference [r], or 172 millions of miles breadth. And if to that we add the increment cauſed by the ſweep of the Moon, or the excurſion of

[q] The Moon's mean diſtance from the Earth, according to Sir Iſaac Newton's Princip. p. 430, is 60½ ſemidiameters of the Earth, according to which the diameter of the Moon's orbit is 479905 Engliſh Miles.

[r] Concerning the diſtance between the Sun and the Earth, there is a great diſagreement between the former and the latter aſtronomers, occaſioned by the diſagreement between their obſervations of the Sun's horizontal parallax (which is equal to the Earth's ſemidiameter viewed at the Sun). Tycho making it three minutes, Kepler but one, Bullialdus 2 minutes 21 ſeconds, and Riccioli but 28 ſeconds. Conſequently the diſtances ariſing from hence are leſs than thoſe of the latter aſtronomers. The very ingenious and accurate Monſ. de La Hire, in his Tabul. Aſtron. thinks the Sun's horizontal parallax to

of her orb beyond the *magnus orbis*, we ſhall have a ſpace yet broader by near 280 thouſand miles. But as vaſt a ſpace as this ſeems to be, yet it is not ſuch as to cauſe either the Earth or Moon to claſh with any of the other celeſtial globes, as I have ſaid; nay, ſo far from that, that not ſo much as their ſhade approaches any of them. In which caſe, what ample orbs muſt the three ſuperior planets have; what a ſpace is neceſſary for them and their more numerous moons to

to be not above 6 ſeconds, and his diſtance therefore to be 34377 ſemidiameters of the Earth, or 136952807 Engliſh miles. But although his obſervations were made ſince, yet I ſhall make uſe of Monſ. Caſſini's number, being deduced from very ingenious and accurate obſervations of the parallax of Mars, and agreeing nearly with the determination of two great men, Mr. Flamſteed and Mr. Huygens, and I may add Dr. Halley too, who make it about 10 or 12000 diameters of the Earth. That great aſtronomer (Monſ. Caſſini I mean) aſſigns a number between them in his Les Elemens de L'Aſtron. § 37. " That the Sun's parallax being ſuppoſed to be 9½ ſeconds, gives the diſtance of the Sun from the Earth 21600 ſemidiameters of the Earth: which are equal to 86051398 Engliſh miles. And imagining the *magnus orbis* to be a circle (as it is indeed an ellipſis not much differing from a circle, the double of that number is the length of its diameter, viz. 172102795 Engliſh miles.

These numbers are different from thoſe I have aſſigned in my Phyſico-Theol. B. I. Ch. 4. note 5. from a miſtake at that time.

perform

perform their much larger courses in? And accordingly such spaces, they and the rest of the planets are all found to have: Saturn an orb of 1641526386 English miles diameter; Jupiter an orb of 895134000 miles; Mars of 262282910 miles; Venus of 124487114 miles; and Mercury an orb of 66621000 English miles [a]: all of them spaces so accurately laid out, and distances so duly proportioned to their revolutions about the Sun, that abundantly manifest infinite wisdom to have been concerned in their appointment, as I intend to shew in a proper place.

But now after this account of this so prodigious a space as that of our solar system is, what is it to the nearly infinite expansum occupied by the rest of the heavenly bodies! Of which we may have a faint adumbration by considering the distances, which, with the greatest probability of observation and reason, are assigned to the fixt stars. In order to the making an estimate of which matter, let it be supposed (which is usually allowed) that the fixt stars are so many Suns;

[a] These numbers are deduced from the distance between the Sun and Earth assigned in the preceding note, and Sir Isaac Newton's distances of the planets from the Sun computed from their periods in his Principia, L. iii. Phænom 4. and are, as I humbly conceive, much more accurate than other calculations that I have met with.

that they are of the ſame, or nearly the ſame magnitude as our Sun is; and that the difference of their magnitudes ariſeth from the difference of their diſtances; if ſo, then it will follow, That the fixt ſtars are each of them as much farther from us than the Sun, as their apparent diameters are leſs than that of the Sun[t]. And foraſmuch as few of them appear otherwiſe than as points even through our beſt teleſcopes, therefore how prodigiouſly farther muſt they needs be from us than the Sun is, to cauſe their appearance to be ſo very much leſs than the Sun? For an example, let us take one of the fixt ſtars ſuppoſed to be neareſt to us, as being the brighteſt and largeſt, namely Syrius. Now this, by accurate obſervations[u], hath been found to be in appearance 27664 times leſs than the Sun; and conſequently, by the foregoing rule, it is ſo many times farther off than the Sun is, which will amount to above two millions of millions of Engliſh miles. And if ſo, what an immenſurable ſpace is the firmament; wherein a great number of ſtars leſſer and leſſer, and conſequent-

[t] Compare the ſagacious Dr. David Gregory's demonſtration of this in his Aſtron. L. iii. Prop 56, 60, and 61.

[u] See Mr. Huygens in Coſmotheor. p. 137.

ly (according to the foregoing ſuppoſition) farther and farther off, are ſeen with our naked eye and many more diſcovered with our glaſſes, and ſtill many more and more with better glaſſes [v], in all probability many others that eſcape the reach of our utmoſt art to deſcry: which may conſequently be as far diſtant from thoſe we ſee, as thoſe are from us.

[v] In viewing the planets with my longer glaſſes, eſpecially the planets of a weaker light, it often falls out that divers of the fixt ſtars, and ſome of them very ſmall, preſent themſelves at the ſame time within the glaſs, notwithſtanding its area is not ſufficient to contain both Jupiter, and his moſt diſtant ſatellites. By which it means it is ſometimes difficult to diſtinguiſh between thoſe fixt ſtars, and the ſatellitesof the planets. Thus I have ſometimes been ready to fancy that I ſaw one or more ſatellites, near Mars, until by future obſervations I perceived they were only ſome of the teleſcopic fixed ſtars lying in the way of Mars. So about Saturn, I have often diſcerned the likeneſs of many ſatellites, but I am not ſure I ever ſaw above three. From whence it is manifeſt, that in all parts of the Heavens, there are many ſtars which preſent themſelves to our eye through our long glaſſes, that are otherwiſe inviſible to us.

CHAP. IV.

PRACTICAL DEDUCTIONS FROM, AND REFLECTIONS UPON THE MAGNITUDE OF THE HEAVENS.

HAVING ſet forth the prodigious magnitude of the heavenly ſpace, and of the bodies therein contained, before we proceed farther, let us pauſe a little to conſider what influence theſe things ought to have upon us.

And, in ſhort, who can behold the regions above, and conſider the things therein contained, and at the ſame time not own them to "declare "the glory of God?" Who can view that immenſurable firmament in which thoſe bodies are, and not acknowledge his handy-work? We admire, as juſtly we may, the vaſt bulk of this our own globe; but when we conſider how much it is ſurpaſſed by moſt of the heavenly bodies, what a point it degenerates into, and how very little more even it, and what we call its great orb together alſo, are, when ſeen from the heavens, this

this gives us a juſt and noble idea of the infinite Creator's works, ſuch as is worthy of God, and ſuch as may make us ſlight, not overvalue this little heap on which we dwell, and cauſe our thoughts and deſires to ſoar among the heavenly glories. But for an application of theſe conſiderations, let us hear Seneca's reflections upon the matter, [w] who on this account recommends virtue, not purely "becauſe it is a noble thing in its own nature, and a great bleſſing to be free from evil, but alſo becauſe it enlargeth the mind, and prepares it for the knowledge of heavenly things, and makes it fit to aſſociate with God. [x]—" Then ſaith he, the mind hath the conſummate and full good of our human ſtate, when having conquered all evil, it ſoars aloft, and wandering among the ſtars above, it is able to deride the ſtately ſtructures of the wealthy, and all their riches.—Neither, ſaith he, can it contemn the porches and roofs ſhining with ivory, the clipped groves, and the pleaſant ſtreams conveyed to their houſes, until it hath wandered throughout the world, and from above, looking down upon this little globe, covered in a great meaſure by the ſea, and where

[w] Nat. Quæſt. L. i. Præfat.

[x] Qui in conſortium DEI veniat.

not ſo, ſlovenly, and either burnt up in one part, or frozen in the other; it then ſaith to itſelf, is this that little point that is divided among ſo many nations by fire and ſword? O how ridiculous are the bounds of mortals, when this river divides this nation, that mountain boundeth another, and that deſart another? For as for this world, ſaith he, it is a point in which ye ſail, in which ye war, in which ye diſpoſe of kingdoms. But above, are vaſt ſpaces into the poſſeſſion whereof the mind is admitted, on condition it hath brought but little of the body along with it, that it hath cleanſed itſelf from every filthy thing, and being diſengaged from the world, hath made itſelf illuſtrious, by being expeditious and light, and content with little things. When ſuch a mind, ſaith he, hath touched thoſe celeſtial regions, it is then nouriſhed and grows; and, as if delivered from its bonds, it returns to its original ſtate. And this argument it hath of its divinity, that it delights in divine matters, and is converſant with them, not as things ſtrange, but its own. There it ſecurely beholds the riſing and ſetting ſtars, their different courſes, &c. There this curious ſpectator diſcuſſes every thing, and ſearches out every thing. And indeed what ſhould it do but pry into thoſe matters,

ters,

ters, fince he knows they belong to himfelf. Then he contemns the narrow bounds of his habitation in this world.—And here at laft he learns what he hath long enquired after: there he begins to know God. [r]

[r] Illic incipit DEUM noffe.

BOOK II.

THE GREAT NUMBER OF THE HEAVENLY BODIES.

CHAP. I.

A GENERAL VIEW OF THE NUMBERS OF THE HEAVENLY BODIES.

HAVING in the preceding book given a demonſtration of God, from the magnitude of the heavenly bodies, I ſhall do the ſame in this from their number; a number ſo great, that we cannot view and conſider them without aſtoniſhment. Were there no more of them than the ſun and the planets (both primary and ſecondary) ſuppoſed to move about him, there would be be a number ſufficient to manifeſt an Almighty and wiſe Creator. But when we view the heavens, and ſee ourſelves ſurrounded with ſo prodigious a number of illuſtrious bodies, of various magnitudes: when we go to other parts of this our globe, from the northern, ſuppoſe, to the ſouthern pole, and there diſcover a great multitude of other ſtars that were never ſeen in our hemiſphere; when we perceive the heavens thick beſet with them in every place: and when (as I already hinted), we view the heavens with our glaſſes, and diſcover many more than our naked eye could reach; and when we again view them with better and better inſtruments, and ſtill diſcover more and more of thoſe ſtarry globes; when particularly we ſurvey what they call the milky-way, and ſee the prodigious number, I may almoſt ſay cluſters of ſtars, that fill that region of the heavens, and cauſe that remarkable whiteneſs there: I ſay, when we ſee ſuch prodigious numbers of thoſe heavenly bodies, which no art of man can number; and when we farther conſider, that in all probability we do not ſee the half, nay perchance not the thouſandth part of what the heavens do contain; as we cannot but be ſtruck with amazement at ſuch a multitude of God's glorious works. ſo we cannot but own the great Creator in them; and we are worſe than men, if we do not give him his due praiſes.

CHAP.

CHAP. II.

THAT THE FIXT STARS ARE SUNS ENCOMPASSED WITH SYSTEMS OF PLANETS.

ALTHOUGH the number of the erratick and fixt heavenly bodies we fee, are fufficient to fet forth the exiftence, and praifes of their great Creator, yet there is one thing more that I cannot eafily pafs over (though it hath only high probabilities for it) becaufe it gives us a far more noble and agreeable idea of the creation, than the world was ever, that we know of, acquainted with before; and that is, that the beft and moft learned modern aftronomers do generally fuppofe the great multitude of fixt ftars we fee, or imagine to be in the univerfe, to be fo many funs, and each of them encompaffed with a fyftem of planets like our fun.

And that the fixt ftars are funs, or of much the fame nature as our fun, there is great reafon to conclude.

1. Becaufe

1. Becaufe they are bodies no lefs immenfe (as I have faid) than the fun, but only diminifhed, in appearance, by their prodigious diftances from us.

2. Becaufe they fhine by their own native light, not by any borrowed from the fun. For fo great are their diftances from the fun, and from us alfo, that it is not poffible their light fhould be received from the fun, and reflected to us, as that of the moon and other planets is. And withal, fo brifk and vivid is their light, and fo very fmall their apparent diameters, when divefted of their glaring rays, and made to have their true appearance through our telefcopes, that no queftion is to be made, but that they fhine by their own innate light, as our fun doth.

And if the fixt ftars are fo many funs, certainly they minifter to fome grand ufes in the univerfe, far above what hath ufually been attributed unto them. And what more probable ufes, than to perform the office of fo many funs? that is, to enlighten and warm as many fyftems of planets; after the manner our fun doth the erraticks encompaffing it. And that this is the ufe and office of the fixt ftars, is probable.

1. Becauſe this is a far more probable and ſuitable uſe for ſo many ſuns, ſo many glorious bodies, than to ſay they were made only to enlighten and influence our leſſer, and I may ſay our inferior globe; which another moon or two, one or two of thoſe very ſuns ſet nearer to us, would have better done, than all the whole train of heavenly bodies now doth. But inſtead of this, many of them, nay, perhaps the greateſt number of them, are at ſuch immenſe diſtances (as ſhall be ſhewn under the next head) that they are out of the reach of our naked eye. In which caſe, what uſe is it likely ſuch great numbers of ſuch immenſe, unſeen, far diſtant bodies can be to our world, when there are ſo many already of divers magnitudes of thoſe that fall under view, that (beſides other much greater uſes they may ſerve in the univerſe) do miniſter to our help and comfort here upon earth in ſupplying the abſence of the ſun and moon by night?

2. From the parity, and conſtant uniformity obſervable in all God's works, we have great reaſon to conclude that every fixt ſtar hath a ſyſtem of planets, as well as the ſun. For it is certain that the ſun is a fixt ſtar to the fixt ſtars, as they are to the ſun. And in this caſe, if (as the juſtly

justly renowned Mr. Christian Huygens argues) [z] "we should imagine ourselves to be placed somewhere in the heavenly regions, as far from the sun as from the fixt stars, we should then perceive no difference between the one or the other. For it would be very unlikely that we should see any of the solar planets, either by reason of the diminishing of their light, or because their orbs would sink into the same lucid point with that of the sun. Being then so placed, we should imagine all these stars [both sun and fixt stars] to be much of the same nature and kind; and from a view of any one of them nearer to us than the rest, we should make our judgment of them all. And now being, saith he, by the favour of God, admitted so near one of them, namely the sun, as to see six lesser globes revolving round about him, and other secondary ones revolving round some of them; why ought we not to have the same judgment of the rest of those suns, as of this, and think it altogether probable that this is not the only star of all the number that is encompassed with such a train, or in any respect excels the rest? neither also that this star alone revolves round its own axis, but rather that all the rest have somewhat of the same kind also." And so that learned person goes on in the further pursuit of his ingenious argument.

[z] Cosmotheoros, p. 123.

3. Befides thofe ftrong probabilities, we have this farther to recommend thofe imaginations to us, that this account of the univerfe is far more magnificent, worthy of, and becoming the infinite Creator, than any other of the narrower fchemes. For here we have the works of the creation, not confined to the more fcanty limits of the orb, or arch of the fixt ftars, or even the larger fpace of the *primum mobile*, which the ancients fancied were the utmoft bounds of the univerfe, but they are extended to a far larger, as well as more probable, even an indefinite fpace: as was fet forth in the firft book. Alfo in this profpect of the creation, as the earth is difcarded from being the centre of the univerfe, fo neither do we make the ufes and offices of all the glorious bodies of the univerfe, to centre therein, nay, in man alone, according to the old vulgar opinion, that "all things were made for "man [a]." But in this our fcheme we have a far more extenfive, grand, and noble view of God's works: a far greater number of them: not thofe alone that former ages faw, but multitudes of others that the telefcope hath difcovered fince; and all thefe far more orderly placed throughout the heavens, and at more due and agreeable dif-

[a] See Phpfico-Theol. B. ii. c. 6. n. 3.

tances,

tances, and made to ferve to much more noble and proper ends; for here we have not one fyftem of fun and planets alone, and one only habitable globe, but myriads of fyftems, and more of habitable worlds [b], and fome even in our own folar fyftem, as well as thofe of the fixt ftars. And confequently if in the fun and its planets, although viewed only here upon the earth at a great diftance, we find enough to entertain our eye, to captivate our underftanding, to excite our admiration and praifes of the infinite Creator and Contriver of them; what an augmentation of thefe glories fhall we find in great multitudes of them! in all thofe fyftems of the fixt ftars throughout the univerfe, that I have fpoken of and fhall have occafion to mention again in the next chapter:

[b] See the preface, p. 45.

CHAP.

CHAP. III.

OF NEW STARS.

BESIDES the planets of our Solar ſyſtem, and the wonderful number of fixt ſtars, there are ſome others, which are called New Stars, which ſometimes appear and diſappear in divers parts of the Heavens, and will deſerve a place here.

Some of theſe new ſtars have been taken notice of as early as Hipparchus's time, " who ſeeing " ſuch a new ſtar, and doubting whether it often " happened, and whether the ſtars we take to be " fixt were ſo or no;" he therefore (as Pliny tells us [c] " ſet upon numbering the ſtars for " poſterity; a difficult taſk," he ſaith, " even for a God: and by proper inſtruments he marſhalled them in ſuch order, that their places and magnitudes might be known: by which means it might be eaſily found, not only whether they

[c] Nat. Hiſt. L. 2. c. 26.

decayed

decayed and perifhed, or were again renewed; but alfo whether any of them changed their places or had any motion, as alfo whether they increafed or decreafed." Thus Pliny.

Since which time many other fuch new ftars have been taken notice of by others. To pafs by the new ftars in Hadrian's, Valentinian's, Honorius's, and Otto's times, I fhall name only fuch as have been more lately taken notice of by men of good judgment in thefe matters; fuch were thofe new ftars obferved by Tycho Brache, David Fabricius, Janfon, Bayer, Kepler, Marius, Byrgius, Holwarda, Hevelius, Montanari, Bullialdus, Caffini, our Mr. Flamfteed, and fome others; [d] to which may be added a new ftar that appears at this very time I am writing, in the neck of the fwan; the fame in all probability that hath been feen before by Mr. Kirch[e] in 1687, and

[d] For a catalogue of thefe and other new ftars, the conftellations in which they appeared, and other matters relating to them, I fhall refer to Riccioli's Almageft. Lib. 8. Sect. 2. Chap. 1. Hevelii Prodorm. in his defcription of the comet in 1665, p. 433. the Appendix to Mercator's Aftron. and Mr. Lowthorp's Abridg. vol. i. p. 247.

[e] In the Mifcellanea Berolinenfia, p. 210 Mr. Kirch faith, he, for fome time, fought this ftar in vain, but at laft on 6-16 of Auguft, 1687, he found it with the help of an eight foot tube, but very fmall:

and 1688, and perhaps by Bayer long before, as alſo Hevelius and others.

Of theſe new ſtars, there is reaſon to imagine there may be many, by reaſon they are not confined to any one part of the heavens, but appear and diſappear in divers conſtellations, and divers parts of thoſe conſtellations, as in Caſſiopeia, the ſwan, the great bear, Andromeda, Eridanus, the whale, the ſhip, and divers other parts of the heavens.

What theſe new ſtars are, is hard to determine. Meteors they cannot be, becauſe they are of long continuance, and much too far off, for bodies that emit ſo little light as metors do, to be ſeen by us. And as for other opinions about them, they are too many, and too frivolous (ſome of them to be named) [f], except one or two of the moſt probable. Among which, one is of ſome

ſmall: and that it grew bigger and bigger, ſo as on October 23, to be ſeen with the naked eye, untill having arrived to its greateſt magnitude, it again became leſs and leſs, and at laſt inviſible even in a teleſcope. By frequent obſervations, he diſcovered its motion to be very regular, and its period to be 404½ days.

[f] If the reader hath a mind to ſee a variety of theſe opinions, he may find them largely enough handled in Riccioli's Almageſt. ubi ſupra, c. 17.

perſons

persons that think they may be such stars as have one side darker than the other, as one of Saturn's satellites is supposed to have, and so appear only when the bright side is turned towards us, and disappear as the darker takes place. Some think they may be fixt stars that expire in light and vapours [g], and are again rekindled, and recruited by the access of comets. Others take them to be comets themselves. But if I may be admitted to speak what was formerly my own opinion, I rather took them to be erratick of some kind or other, and that for these reasons:

1. From some of them, as I thought, seeming to change their places, and appearing sometimes farther off, and sometimes nearer unto other stars: as I have said in the preface, p. 41.

2. From that increase and decrease of their light and magnitudes which is constantly observed in them, they being at first obscure, and hardly discernible, but by degrees growing brighter and brighter, till some of them equal the light of Venus; and others the light of the fixt stars, of the first, second, and third magnitudes: and then again as gradually grow less and less, till they utterly disappear.

[g] This is what Sir Isaac Newton surmises in his Princip. l. iii. Prop. 42.

3. From their periodical motion and return after a certain time. This indeed hath not been fo carefully and judicioufly taken notice of as it deferves, or fo as to bring their periods under certain determinations; but yet in fome of Hevelius's and Caffini's obfervations, it hath been difcovered that fome of the fame ftars have returned, as particularly that in the whale's neck. and that which now appears in the fwan's neck, which as I juft before (p. 246.) faid, hath a period of $404\frac{1}{2}$ days, according to Mr. Kirch's obfervations.

Thefe were my reafons for fufpecting thofe new ftars to be erraticks, rather than fixt ftars either recruited, or having dark and light fides.

But the grand difficulty is, what kind of erraticks they are, whether wandering Suns or planets (like ours) of other fyftems? That they fhould be wandering funs, is fomewhat odd to affert: and of what ufe they fhould be, is hard to imagine, fince there is nothing of this kind in the univerfe, that we know of, that may affift our imagination.

And as to the latter opinion, I confefs I have been much inclined to fufpect that they might be planets

planets revolving round fuch funs, as caft a much fiercer and more vigorous light than the fun doth: and that thefe their planets might be more denfe than ours, and have furfaces more ftrongly reflecting light, and perhaps be much larger too. But notwithftanding that planetary reflected light may be fent to very great diftances by thefe means, yet without extravagant fuppofitions of this nature, it may be doubted whether it would reach us, fo far off as the fixt ftars are. And befides this, another doubt is, that although there are divers ftars near thofe new ftars of greater magnitudes than any of thofe new ftars are, (which I have had the fortune to fee); yet I can fcarce think them big enough, to conclude them to be the funs about which thofe new ftars (if planets) move. And therefore being uncertain what to determine in fo intricate a matter, I fhall leave it to future better obfervations (which the late long dark weather hath hindered me in the profecution of) which I hope may afford us fo good light, as may lead us into a much greater knowledge of thofe rare phænomena.

But whatever thofe new ftars are, they are a farther demonftration of God's power and glory: and that there are many more of the grand works

works of the Creation, than what our eyes behold at all, or that we have only now and then a glimpse of. But if they are planets of other systems, some of those erraticks revolving round some of the fixt stars, then do they lay open a still more glorious scene of God's work, and give us such a representation of the state of the universe, that the world never dreampt of before, and that even angels themselves may be amazed at the sight of.

BOOK

BOOK II.

THE DUE

SITUATION

OF THE

HEAVENLY BODIES.

CHAP. I.

OF THE DUE, AS WELL AS GREAT DISTANCE OF THE HEAVENLY BODIES.

I HAVE before taken notice of the immenfe diftance of the heavenly bodies, that it is fuch as makes thofe vaft bodies the fixt ftars (no lefs in all probability, as I faid, than the fun itfelf) to degenerate into fo many points, yea to efcape our eye; nay more than this, that it caufeth even our own great orb which our earth defcribes about the fun, to fink into almoft a point, or at leaſt a circle of but few ſeconds diameter. I ſhall therefore ſay no more on that matter. But that which I ſhall ſpeak of in this book, is the due proportion of the diſtance of the heavenly bodies; that they are not ſet at random, like a work of chance, but placed regularly and in due order, according to the beſt methods of proportion and contrivance. Which will be manifeſt from the following chapters, which will ſhew that the diſtance is ſuch, that none of the globes interfere with one another: but, inſtead of that, are in due and the moſt nice, commodious proportion.

CHAP.

CHAP. II.

THAT NONE OF THE GLOBES OF THE UNIVERSE INTERFERE.

HAD the universe been the work of chance, or any thing but of a wise architect, there would have been a great many blunders and inconveniences in the situation of such a prodigious number of immense globes, as the universe doth contain. Some would have been too near, some too far off, some would have met with, knocked and stopped one the other, and some would have so interfered as to have incommoded the other, some way or other. But instead of this, every globe throughout the whole creation is, as far as it is possible for us to observe, set at such a due distance, as not only to avoid all violent concourses, but also so as not to eclipse or shade one the other, wherever it may be prejudicial, or indeed not useful and convenient, or so as to hinder one another's kindly influences, or to prejudice one another by noxious ones. This is very manifest in our own

own ſyſtem of the ſun; and becauſe we ſee it not otherwiſe, we may conclude it to be ſo in all; unleſs we ſhould make ſome exception for what is ſuſpected (and indeed only ſuſpected) of comets, which, in their approaches towards the earth, are imagined to cauſe diſeaſes, famines, and other ſuch like judgments of God. But this is only ſurmiſe, and what befals the world at other times without the viſible approach of any comet. But however, ſuppoſing, that as comets move in orbs very different from thoſe of the other heavenly bodies, ſo their effects and influences may be as different; yet this may be, and no doubt is (becauſe it may be proved) with the concurrence and by the appointment of the Divine Providence; who, as a governor of the world, might make ſuch noxious globes to execute his juſtice, by affrighting and chaſtiſing ſinful men at their approaches to the earth, and not only ſo, but (as ſome have imagined) to be the place of their habitation and torment after death. But ſuppoſing it to be ſo, yet herein is a kind Providence manifeſted, that their returns to the earth are but ſeldom [h], and their ſtays ſhort, and

[h] There having of late been great expectations among ſome, of a comet appearing this year 1718, it may gratify their curioſity to take notice, in this place, of three comets, whoſe periods, we imagine

and that they take up many years in paſſing the reſt of their orbs.

And now whether we conſider the due ſituation of the greateſt part of the heavenly bodies, whereby neither they, nor their influences do interfere; or the more unuſual poſition and motion of comets, ſtill it appears that a wiſe and careful architect was the contriver and orderer of it all; eſpecially if we join what follows in the next chapter.

agine, are diſcovered, by the great ſagacity and application of our modern aſtronomers. The revolution of the firſt of the three, is ſuppoſed to be performed in 75 years, and to have been the ſame comet that appeared in the year 1682. The ſecond is ſuppoſed to be the comet that was ſeen in the year 1661, and to revolve round in 129 years. And the third is imagined to be that comet which appeared in 1680 and 1681, whoſe period is 575 years. And according to Mr. Whiſton's determinations, the firſt of theſe three comets will again appear in the year 1758, the ſecond in 1789, and the third and laſt not till about the year 2255.

CHAP.

CHAP. III.

OF THE NICE PROPORTIONS OF THE DISTANCES OF THE HEAVENLY BODIES.

AS it is one great demonſtration of the ingenuity and ſkill of an architect to give due proportions to his work; ſo we find this to be abundantly manifeſt in all the bodies of the univerſe that fall under our cognizance: among which we may diſcern a curious order, and that due and nice proportions are ſtrictly obſerved in their ſituation.

How the fixt ſtars are ſituated in reſpect to one another, is impoſſible for us to determine at ſuch prodigious diſtances as they are from us; but they look to us, who can have no regular proſpect of their poſitions, as if placed without any order: like as we ſhould judge of an army of orderly, well diſciplined ſoldiers, at a diſtance, which would appear to us in a confuſed manner, untill we came near and had a regular proſpect of of them, which we ſhould then find to ſtand well in rank and file. So doubtleſs, if we could have an advantageous proſpect of the fixt ſtars, we ſhould find them very commodiouſly, and well ſet in the firmament in regard of one another. And this we have great reaſon to conclude from the rules of parity, from that conſtant harmony, and ſimilitude obſervable among all the works of the creation, which fall under our cognizance: particularly this is evident in this region of the univerſe to which we belong, and which we have a better proſpect of and can ſurvey with our inſtruments, I mean the ſyſtem of the ſun. In this we find every body placed in good order, and at due diſtance, according even to the niceſt rules of proportion.

For the eviction of this matter, let us (according to the moſt received and rational hypotheſis) ſuppoſe the ſun placed in the centre, to influence all his planets with light and heat. Then follow the ſeveral planets, ſurrounding him, not one here, and another there, at all adventures, in a rude manner, like a work of chance, but at due diſtances from the ſun; at proper diſtances from one another; and in ſuch well adjuſted proportion of their velocities and gravities, as makes the ſquares of their revolu-

 tions

tions in proportion to the cubes of their distances. And this is what is discernible in the whole solar system, not only in the primary planets that revolve round the sun, but in the secondary planets also that revolve round them. Thus it manifestly is in the five moons that accompany Saturn, and the four accompanying Jupiter. And a most sagacious contrivance this is, manifesting the presence and conduct of the Creator, in thus chusing this proportion I speak of, rather than any other. For should the power of gravity (for instance) have been so constituted, as to decrease in the proportion of the cubes (instead of the squares) of the distances reciprocally; although it might be possible to adjust a velocity, and I may add, a direction too, so as to make bodies describe perfect circles, yet the least excess or defect of velocity, or the least obliquity of the direction, would make them describe spiral curves, either ascending *in infinitum*, or else descending to the centre. And supposing the orbs (in which those bodies move, and which are supposed, as I said, to be made in proportion of the cubes) to be perfectly circular, the least adventitious force, even but of an atom, abating or increasing the velocity, or changing the direction, would bring on the aforesaid inconveniences. And if the great Creator and

contriver

contriver of the univerſe hath thus wiſely modelled, and cautiouſly methodized this part, this ſyſtem of it where we live, and behold the thing, no great doubt can be made but that he hath done the ſame in the other ſyſtems thereof alſo: that every ſyſtem is ſet at a due diſtance from one another, and every body in each ſyſtem at its due diſtance alſo from their ſun, or fixt ſtar.

And now who can reflect upon theſe things, and not perceive and admire the hand that acteth in them, the contrivance and power of an infinite workman! For where we have ſuch manifeſt ſtrokes of wiſe order, counſel, and management, of the obſervance of mathematical proportions, can we conclude there was any thing leſs than reaſon, judgment, and mathematical ſkill in the caſe? or that this could be effected by any other power, but that of an intelligent Being, who had wiſdom and power ſufficient for ſuch a work: according to the reaſoning of the Stoic in Cicero, who pleads thus [i]: "If thou ſhouldeſt ſee a large and fair houſe, thou couldeſt not be brought to imagine that houſe was built by the mice and weeſles, although thou

[i] Cic. de Nat. Deor. l. ii. c. 6.

ſhouldeſt not ſee the maſter thereof: ſo (ſaith he) wouldeſt thou not think thyſelf very plainly to play the fool, if thou ſhouldeſt imagine ſo orderly a frame of the world, ſo great a variety and beauty of heavenly things, ſo prodigious a quantity and magnitude of ſea and land to be thy houſe, thy workmanſhip, and not that of the immortal gods!" And ſo when we ſee ſuch good order, ſuch due proportions in this region of the univerſe, and have good reaſon to conclude the ſame may be throughout the whole, can we without great violence to reaſon, imagine this to be any other than the work of God?

BOOK

BOOK IV.

OF THE MOTIONS OF THE HEAVENS.

CHAP. I.

THAT THE BARE MOTION OF THE HEAVENS AND EARTH ARE A DEMONSTRATION OF A GOD.

IN treating concerning the motion of the heavenly bodies, it will be neceſſary to take in that of the earth too, it being not eaſy to ſpeak of one without the other. And here there are two things that are manifeſt demonſtrations of the preſence and management of God, namely, that ſuch bodies ſhould move at all, and that their motion is ſo regular.

1. That all thoſe vaſt globes of the univerſe ſhould have a motion, muſt of neceſſity be from

ſome Being that had power enough to put them in motion. For as Lactantius well argues [k], "There is indeed a power in the ſtars, (and the "like may be ſaid of the reſt of the globes) of "performing their motions; but that is the "power of God, who made and governs all "things, not of the ſtars themſelves that are "moved." For it is impoſſible for ſuch lifeleſs, dull, unwieldy bodies to move themſelves; but what motion they have, they muſt receive from ſomething able to move them.

Now this ſome will ſay may be effected by the vortices ſurrounding the ſun, the earth, or other primary mover [l]; or from a vectorial power, or emanation of the ſun [m], or other the like primary movers carrying about and puſhing on ſuch bodies as move about them. But allowing that it is poſſible it might be ſo, yet ſtill we muſt recur to ſome firſt mover, ſome primary agent, who was able to ſet that principal mover into motion: and then the caſe amounts to much the ſame, and the argument hath the ſame force, whether we attribute the motion of one, or all the

[k] Lactant. Divin. Inſtit. l. ii. c. 5.

[l] This was Des Cartes's notion, and of others long before him.

[m] This was Kepler's ſcheme.

the feveral globes to the power of God. For in our folar fyftem, for inftance, if it fhould be thought that the fix primary planets revolving round the fun, received their motion from his revolution round his own axis; yet "let us think (as Plato argues) [a], how it is poffible for fo "prodigious a mafs to be carried round for fo long a time, by any natural caufe? For which reafon (faith he) I affert God to be the caufe, and that it is impoffible it fhould be otherwife." Thus Plato, whofe argument is undoubtedly good, fince, as Ariftotle argues [o], "Every thing that is moved, muft of neceffity be moved by fome other thing; and that thing muft be moved either by another, or not by another thing. If it be moved by that which is moved by another, we muft of neceffity, faith he, come to fome prime mover, that is not moved by another. For it is impoffible that what moveth, and is moved by another, fhall proceed *in infinitum.*"

And now therefore, if in our folar fyftem, we fhould imagine the moon to be wheeled about our earth, by the motion and vectorial power of the earth; and the moons about Saturn and

[a] Plato in Epinom.

[o] Ariftot. Phyfic, L. viii. c. 5.

Jupiter by the motion and vectorial power of thofe planets; and all the primary planets to be turned round about the fun by the power of the fun, yet at laft we muft find out a mover of the fun itfelf, and thofe other primaries; a caufe of fufficient power to wheel about thofe prodigious maffes, of fuch vaft bulks, as have before been affigned to them, and which, befides their own weight, are, according to their former hypothefes, clogged and encumbered with the *vis inertiæ* of all thofe planets whether primary or fecondary, or both, which they drive round. And if this was the cafe, what power can be found fufficient for this work, but that of the fame infinite hand that at firft gave them being?

And fo for all the reft of the moving bodies of the univerfe, fuch as comets, the new ftars before fpoken of [p], and the flow motion of the firmament, or fixt ftars in 25920 [q] years. This latter I fhall fay no more of, becaufe it may not arife

[p] Book II. chap. 3.

[q] Ptolemy made this motion to be one degree in 100 years. But others fince make it to be more. Mr. Street, in his Caroline Tables, make it 1 gr. 20′: Hevelius 1 gr. 24′. 46″. 50‴: but Mr. Flamfteed agrees Riccioli's number to come neareft the truth, viz. 1 gr. 23′. 20″. in 100 years, or 50″. in a year. According to which rate the motion (called the Platonic year) is accomplifhed in 25920 years.

arise from any motion of the firmament itself, but from some other cause [r]. But for comets, what power but that of the Almighty could give them such prodigious projections as their trajectories or orbs are found to have? orbs that run into such amazingly long ellipses as approach to parabolas, that 'tis wonderful how their projectile force should carry them to such immense distances, and their gravity at the same time bring them back, and incomparably retain them in their orbs.

And so for the new stars, which I have said are so many signals of planetary systems dispersed here and there all over the universe, they are all of them so many manifestations and demonstrations of an infinite Being that hath imparted motion unto them: and they are a sign also that there are other globes, besides the sun and its planets, which are moving bodies, even that all the globes in the universe are such, and consequently so many proofs of an Almighty first mover.

Thus

[r] Sir Isaac Newton demonstrates how this may arise from the sphæroidal figure of the Earth. Princip. l. iii. Prop. 21. & l. i. Prop. 66. Corol. 20. See the matter also more easily demonstrated in Dr. Gregory's Astron. l. i. Prop. 64.

Thus the bare motions of the earth, and of the heavens, are ſo many arguments of a Divine Power therein concerned. But we ſhall moreover find an infinitely wiſe, as well as Almighty Power herein tranſacting, by what follows in the next chapter.

CHAP.

CHAP. II.

THE GREAT REGULARITY OF THE MOTIONS OF EVERY GLOBE.

HAVING in the preceeding chapter ſhewn that the giving motion to ſuch immenſe, lifeleſs globes, is the work of God, we ſhall find much greater demonſtrations thereof, if we conſider that thoſe motions are not at random, in inconvenient lines and orbs, but ſuch, as ſhew wiſe deſign and counſel. I ſhall here ſpecify but two examples, becauſe I ſhall have occaſion to ſay more of this matter hereafter. One is, that all the planets ſhould (when their motions were impreſt upon them) have their directions or tendencies given, not in lines tending from the centre to the circumference, or very obliquely, but perpendicularly to the radii. The other is, that the motions and orbits of the planets ſhould not interfere with one another, but tend one and the ſame way, from Weſt to Eaſt, and lie in planes but little inclined, to one another, or when inclined that it ſhould be very beneficially ſo, as I ſhall hereafter ſhew. Theſe and many other instances, and in a word, that every planet should have as many, and various motions, and those as regularly, and well-contrived and ordered, as the world and its inhabitants have occasion for, what could all this be but the work of a wise and kind, as well as omnipotent Creator, and orderer of the world's affairs? a work which is as plain a signal of God, as that of a clock, or other machine is of man. Thus Tully's Stoic [a] argues our present case from the shepherd at Actium, when from the top of an hill he happened first to see a ship sailing in the sea. He was for a while in great amazement and surprise to see such a moving inanimate body, and could not imagine of what a nature it was possible it should be, untill he perceived, by some tokens, that it was made and managed by man. "So, saith he, the philosophers ought to have done, if happily they had any doubts at the first view of the world; afterwards when they should behold its determined and equal motions, and all things managed by established order, and with immutable constancy; they ought then to understand that there is not only some inhabiter in this heavenly, this divine house, but also some ruler and moderator, and

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[a] De Nat. Deor. l. ii. c. 35.

in a manner, architect of so great a work, so able a performance." This conclusion is so natural, so cogent, that any thing but stupid prejudiced blockheads (as those philosophers were) would have naturally and easily made it, "But now, saith the Stoic[t], they seem to me not so much as to have any suspicion of the wonderfulness of the things of the heavens or the earth." And great reason the Stoic had for his surmise. For so manifest a demonstration of a Deity are the motions of the heavens and earth, that if men do not see them, it is a sign of great stupidity; and if they will not see and be convinced by them, it is as plain a sign of their prejudice and perverseness, as will farther appear by considering what an incomparable provision is made for the world's good, by the particular motions which are given to the earth and heavens, namely, the diurnal and periodical motions,

[t] Ibid. c. 36.

CHAP.

CHAP. III.

OF THE DIURNAL MOTION OF ALL THE SEVERAL GLOBES.

AS to the diurnal motion, there is great probability that our earth, and all the heavenly bodies have a rotation round their feveral axes; not all performed indeed in the fame fpace, or length of time, but fome in longer, fome in fhorter times; each time making what we call a day in thofe feveral globes, equivalent, although not equal to the circumvolution of our Earth in 24 hours.

This diurnal rotation is vifible in many of the heavenly globes, and highly probable in our own. In the fun it is very manifeft from the equable motion of its fpots, which fometimes appear on its difk, and have been obferved formerly by Galilæo [u], Scheiner [x], Tardé

[u] Galilæo tells us in the III. Dialogue of his Syftem. Mund. that he was the firft that difcovered fpots on the fun, in the year 1610.

Tardé [y], Malapertius, Hevelius [z], and our countryman Mr. Gascoigne, and Mr. Crabtree [a]; and since them by Mr. Boyle, Dr. Hook, Dr. Halley, Mr. Flamsteed, and others in England, and by Messrs. Cassini,

1610, which he shewed the next year to divers great persons in Rome. That Scheiner sent him two letters by Velserus, under the feigned name of Apelles, to desire his opinion of them; that he concluded them to be alterable, contrary to the received opinion then, of the heavens inalterability; that they were contiguous to the sun, and that their paths over the sun, sometimes in a curve, sometimes a strait line, argue the annual motion of the earth about the sun, and not of the sun about the earth; with more to the same purpose, which may be seen in the sagacious author in his 1st and 3d Dialogues.

[x] Vid. Scheiner's Rosa Ursina.

[y] Vid. Tarde's Astra Borbonia, who took them to be small stars interposing themselves between the sun and us. Of the same opinion also was Malapertius, who gave them the name of Sydera Austriaca.

[z] See Hevelius's opinion of them at large in his Selenography, ch. 5. and in the Appendix.

[a] In their letters, now in my hands, there is an ingenious controversy between those two great men, Mr. Gascoigne, the inventor of the micrometer, and Mr. Crabtree, concerning the Solar spots that appeared about the year 1640, which Mr. Gascoigne imagined to be great numbers of small planets revolving round the sun, at a small distance from him. Mr. Crabtree's answer and opinion may be seen in his letter, which is published with my own observations about the Solar spots from 1703 to 1711, in the Philos. Trans. No. 330.

Caſſini, Picart, and others abroad [b], and of late by myſelf and others too. Theſe ſpots have manifeſtly a motion, and the ſame motion too, as that of a globe moving round upon its poles: for we may perceive them to be perpetually ſhifting their places from the eaſtern to the weſtern limb of the ſun; and in thus doing, their daily ſtages and motion exactly correſpond to the motion of a globe; that is, thoſe ſtages are ſhorter, and the motion of the ſpots ſeemingly ſlower towards the ſun's limb, but near the centre of the diſk, larger and ſwifter; and all in exact proportion to a double line of ſines, or a line of ſines on each ſemidiameter of the diſk.

And farther yet, theſe ſolar ſpots, as they manifeſtly demonſtrate the ſun to be a moving globe, turning round once in ſomewhat above 25 days, ſo they manifeſt themſelves to be ſomething adhering unto, or nigh the ſun's globous body, by means of the different parts and poſitions of the ſun: as in the middle of the diſk, if they are round, towards the limb they become more and more oval or long, juſt as ſuch a like ſpot on a common globe would appear when it is turned

[b] The obſervations of thoſe great men (which are diſperſed about in the Ph. Tran.) may be ſeen at one view in Mr. Lowthorp's Abridgment, vol. 1. p. 274.

turned ſo as to be viewed by us ſideways, or going out of ſight.

And laſtly, another thing obſervable in and from theſe ſpots is, that they deſcribe various paths or lines over the ſun, ſometimes ſtrait, ſometimes curved towards one pole of the ſun, ſometimes towards the other, exactly correſponding to the different poſitions of the earth in reſpect of the ſun throughout all parts of the year.

Thus in that vaſt maſs, the ſun, we have manifeſtly ſuch a diurnal motion as I ſpake of, or circumvolution round its axis; a motion conſtant and regular, and doubtleſs of as great uſe to ſome office or other, in ſome part or other of the univerſe, as the motions of the earth, are to the inhabitants thereof: and a motion therefore this is, demonſtrating the concurrence of the Almighty,

Neither is it the ſun alone that undergoes a diurnal rotation, but moſt, if not all the erraticks about him. Saturn indeed is at ſo great a diſtance from us, that we have not been able to perceive whether or no he hath ſuch a rotation; but as the other planets have it, and there is full as much occaſion for it in Saturn as in them, ſo

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there is no great doubt to be made, but that he hath ſuch a like diurnal motion, accommodated as well to his ſtate, as it is in the earth and the reſt of the planets.

So Jupiter is diſcovered to have manifeſtly a motion round upon its axis from Eaſt to Weſt, in the ſpace of 9h. 56′, as Monſ. Caſſini [c] by many repeated obſervations in the year 1665, and other following years, firſt found from the ſpots obſervable on it; of which there are two kinds, which I myſelf have often ſeen as well as others before me; a ſhort account of which (although it be a digreſſion) may not be unacceptable to many readers. One kind of thoſe jovial ſpots is only the ſhadow caſt upon the planet by the ſatellites intercepting the light of the ſun, when they are interpoſed between the ſun and Jupiter: the others are ſuch as are really in the body of that planet, after the manner of thoſe we ſee in the moon, but not permanent as they are. And by the motion of theſe latter ſpots, it is manifeſt, not only that Jupiter revolves round in the time mentioned, but that it is a moving globe alſo, by reaſon (as was ſaid of the ſun) thoſe ſpots move ſwifter, and in larger ſtages towards the middle

[c] See his obſervations in the Memoirs de Mathem. & de Phyſique for Jan. 1692.

middle, than towards the limb of Jupiter's disk. Also such spots as are round about the middle, appear long or oval towards the limb, or edge of the disk; as was before observed of the sun's spots.

As to Mars and Venus, they are both discovered to have spots, or parts lighter and darker, as well as Jupiter, and to have a motion also as he hath. Of those spots in Mars, Dr. Hook had divers views in the year 1665, which he hath given us figures of [d]: and from thence concluded that planet had a motion, although he could not determine in what time it was performed. But Mr. Huygens expresly saith [e] it is performed in the space of 24h. 40'. But for the motion of Venus, Monf. Cassini could perceive the spots to change their place, and that the planet had a motion, although he could not make out what it was [f].

Thus are the primary planets discovered to have a diurnal rotation, or somewhat very like it at

[d] See Philos. Trans. No. 11, 14.

[e] Cosmotheor. p. 24.

[f] Mr. Cassini's observations dispersed in the Phil. Trans. may be seen at one view in Mr. Lowthorp's Abridg. vol. I. p. 383, & 425.

at leaſt, all except Saturn, as I ſaid, and Mercury, and our own globe. And as to theſe we have very little, or no reaſon to imagine but that they move as well as the reſt; only we cannot perceive it in Mercury, by reaſon of its proximity to the ſun, and that its elongations are never ſo great, nor ſo long, as to enable us to have any good and ſufficient views of him with our teleſcopes.

And as for our own globe, it is very viſible, that either that moves round in 24 hours, or that the ſun and all the heavens move round it in the ſame time. And which of theſe two is the moſt agreeable to the uſual courſe and methods of nature, which performs all its works in the moſt compendious, facile way, let every one judge. And is it not far the moſt compendious, ready and eaſy way, that the terraqueous globe ſhould wheel about in 24 hours, than that ſo many vaſt bodies of the heavens ſhould be turned about it in that time? Is it not as poſſible, yea as probable, that our leſſer globe ſhould be ſo turned about, as thoſe more maſſy globes of the Sun, Saturn, and Jupiter, are about their axes? But I ſhall not enter into a detail of the arguments for the earth's motion, and the objections made againſt it, becauſe I have done it in the preliminary diſcourſe.

Thus

Thus having taken a profpect of the diurnal motions of the great globes of the univerfe, that fall beft under the cognizance of our inftruments, and found that many, and probably all of them, have a rotation round in a determinate time; if to this we add the convenience and prodigious ufe of this motion to the feveral refpective globes, we fhall find that an infinitely wife and kind, as well as omnipotent Being, was the orderer thereof. For were thofe globes always to ftand ftill, efpecially the erraticks that owe their light and heat to the fun, in this cafe, one half of them would be dazzled and parched with everlafting day, whilft the other would be involved in everlafting night and darknefs. And what the confequences would be, we may beft judge from what would befal our own globe, without the kindly alterations of day and night; and that is, that it, at leaft a great part of it, would fcarce be habitable, it would neither agree to the ftate of man, or any other animals; nor to that of vegetables, or indeed any other creature. For one half of the globe would be burning up, at leaft too much drying, and exhaufted with the beams of the fun, whilft the other would be immerged in, and deadened with too long night. And in fuch a cafe, how would the great works of nature, fo ferviceable to the world, be per-

 formed?

formed? How, for inftance, could the vapours be raifed to fupply the earth with cooling clouds, and fertile fhowers? How could the winds be excited to fan the atmofphere with their pleafant and healthful gales? How could the tides be produced, which by their conftant agitations keep the waters fweet and clean, and prevent their poifoning the world?

And as the courfe and functions of nature, would be thus affected, fo would the ftate of the creation be no lefs. For how could thofe of the vegetable kingdom be animated and excited by the kindly heat of the day, and then again tempered and invigorated by the no lefs kindly dews and influences of the night? How could men and all other animals difpatch their bufinefs, gather their food, and perform all the various labours and offices of the day, and then recruit and repofe themfelves with reft, fleep, and due perfpiration, and whatever elfe may be owing to the falutiferous influences of the night, and abfence of the fun?

Thefe, and ten thoufand as great inconveniencies as thefe, would be the certain events of the want of this diurnal motion of our globe. And

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as the reſt of the globes have their ſhares in the like motion, ſo we may very reaſonably imagine that it is no leſs uſeful and beneficial to them than it is to us, and that the inconveniences of the want of it would be as great.

CHAP. IV.

OF THE ANNUAL OR PERIODICAL MOTION OF THE PRIMARY PLANETS.

BESIDES the motion treated of in the preceding chapter, there is another, which is as clear a manifeſtation of the great Creator as that, namely the periodical or annual, which is viſible in ſome of the great globes, and probable in many others. Among the fixt ſtars it is highly probable ſomething of this nature is: as appears from thoſe new ſtars which I have before taken notice of, which, as I have ſaid, ſometimes become viſible to us, in one part of their orbits, and again diſappear in other parts of them. But theſe ſyſtems being out of the reach of our beſt glaſſes, I ſhall paſs them by, eſpecially becauſe in our own ſolar ſyſtem we have abundantly enough to entertain us in this demonſtration of God.

For it is very viſible, without the help of the teleſcope, that every planet of the ſolar ſyſtem hath

hath this periodic motion I am ſpeaking of. For it is manifeſt, that either the ſun and the planets move about the earth, the one in the ſpace of a year, and the reſt in other times; or that the earth and the other planets move about the ſun in ſuch times. But let us (as I have all along done) ſuppoſe the latter, that the ſun is fixt in the centre, without any other but its diurnal rotation in $25\frac{1}{4}$ days; in this caſe we ſhall have the ſeveral primary planets revolving round the ſun in an excellent and due order, by the exacteſt rules of ſuch a noble ſtructure, ſuch an admirable oeconomy, and that is in times (as I ſaid) in ſquare proportion to the cubes of their diſtances. So that we ſee Mercury to perform its period in near 88 days: Venus (the next in order to the ſun) its period in ſomewhat above 224 days: then the earth, with its companion the moon, in $365\frac{1}{4}$ days: then Mars in about 687 days: next him Jupiter in about 4333 days: and laſtly, Saturn in ſomewhat above 10759 days.

To this ſo ſtrict an order of the periods of thoſe planets, we may add the conſideration of the different paths of their periodical and diurnal motion: that they lie not in a very different plane, as quite a croſs, or the like: nor exactly in in the fame plane, but a little crofling one another; the diurnal courfe lying in, or parallel to the Equator; but the other in the broad path of the Zodiack, at an inclination of $23\frac{1}{2}$ degrees.

And a glorious contrivance this is for the good of our globe, and doubtlefs no lefs for all the reft that fympathize in the like motion. For was the earth's periodic motion to be always in the fame plane with that of the diurnal, we might indeed be fometimes nearer to, and fometimes farther from the fun; but at the fame time mifs of thofe kindly increafes of day and night, together with fuch ufeful directions of the funbeams, which the advances of the earth to one or other of the poles caufe [g]: which two things are

[g] There are two caufes of the great difference between the winter and fummer, heat and cold. One is the fhorter or longer continuance of the fun above the horizon: in fummer long, which increafes the heat, as much as it lengthens the day: in winter fhort, which diminifhes the heat, as it fhortens the day; and augments the cold, as it lengthens the night. The other caufe is the oblique or perpendicular direction of the fun's rays, the oblique being weaker than the perpendicular; as is evident from Galilæo's experiment, in his Syftema Mundi Dial. 1. by holding a paper turned up at right angles, or a book half open, over againft an illuminated white wall; where it may be obferved that the fide oppofite to the wall, which the rays ftrike perpendicularly, is far more light and white than the other fide, on which the rays fall obliquely. The fame it is in the incidence of the fun's rays on any plane, namely, the

are the real cauſes of our ſummer and winter, ſpring and autumn, and not our being nearer unto, or farther from the ſun. For thoſe benefits

the rays are ſo much ſtronger, and the plane the more warmed and enlightened, as the rays are more or leſs perpendicular; and that on two accounts: 1. Becauſe the perpendicular rays ſtrike with greater force than the oblique. As in Fig. 4. the rays R R ſtrike the plane A P more forcibly than the plane O B. The action or force of which percuſſion is (like that of all other impulſes) as the ſine of the angle of incidence. So the force of the rays R R upon the oblique plane O B, is as the ſine only of R O B, whereas that force upon A P is as the whole ſine of 90 degrees, or angle R O P 2. Another reaſon is, That a greater number or quantity of rays fall within the compaſs or area of any plane in a perpendicular than oblique direction. This will be manifeſt from the bare inſpection of Fig. 4. Where it may be obſerved that all the rays between R R and O p fall on the plane A P; but only about one half of them would fall upon an oblique plane of the ſame length, if it was O b: or (which is the ſame thing) near as many rays would fall off O b, turned up to O b, as fall upon it. Alſo it may be obſerved farther that as the line O B is longer than O p, ſo are the ſpaces between the rays larger in O B than O p; and conſequently fewer rays fall on O B for its length, than on O p for its length, or the rays are denſer, or more compact in O p than O B. And when they are ſo, they are ſo much the ſtronger, as is evident from the collecting and condenſing the ſun's rays by a burning glaſs.

What the particular power of the ſun's rays is in all directions, quantities, and impulſes, falls under mathematical calculation; but I need not trouble the reader with it, but ſhall refer to the ingenious Dr. Wolfius, (mathematical profeſſor of Hall) his Elementa Aerometriæ. And as for the proportional degree of the ſun's heat in all latitudes, and its altitudes, our moſt acute Savilian Profeſſor, Dr. Halley, hath given us a neat and clear method for computing it in Philoſ. Tranſact. No. 203.

fits (we at leaſt that inhabit towards the northern pole) have at the contrary ſeaſon, when we have moſt need of them, viz. the ſun's proximity, in winter; its greater diſtance from us in ſummer: as is manifeſt from the increment of its apparent diameter in winter to 32', 47", and the decrement thereof in ſummer to 31', 40" [h].

And now for a concluſion of this chapter concerning the periodic motions of the primary planets, we may take up the argument of Hugo de S. Victore [i]. "who commandeth the ſun to deſcend through the winter ſigns? And who again cauſeth him to aſcend through the ſummer ſigns? Who

[h] Monſieur de la Hire, in his Tabul. Aſtron. makes the ſun's ſemidiameters to be December 30. 16', 22", and June 30, 15'. 49". But Mr. Flamſteed in his Lunar Tables added to Mr. Horrox's Poſthumous Works, makes the greateſt to be 16'. 23", the leaſt 15'. 50", and the French academiſt 16'. 23", and 15'. 50". V. Recueil d'Obſerv. Les Elemens d'Aſtron. p. 22.

Beſides the alteration of the ſun's apparent diameter, its ſwifter motion in winter about the ſolſtice by about a 5th part, is an argument of its being then nearer the earth. From whence it comes to paſs, that from the vernal to the autumnal æquinox, there are about eight days more than from the autumnal to the vernal.

[i] *Quis ſolem per hyberna deſcendere ſigna præcipit? Quis rurſum per æſtiva ſigna aſcendere facit? Quis eum ab oriente in occidentem ducit*

Who leads him from East to West? And who again brings him back from the West to East? All these things are very wonderful, but to God alone possible."

ducit? Quis iterum ab occidente in orientem revehit? Hæc cuncta sunt mirabilia, sed soli Deo possibilia. Didascal. l. vii. c. 8.

CHAP.

CHAP. V.

OF THE PERIODICAL MOTION OF THE SECONDARY PLANETS.

HAVING confidered the periods of the primary planets, let us next caft our eye upon thofe of the fecondaries. And among thefe we fhall find the fame compleat order and harmony as among the laft. Thus Saturn's five moons, and Jupiter's four, and our own about the earth, have each of them their determinate times; fome longer, fome fhorter intervals of time; in the fame due proportion, as I fpake of among the primaries.

Befides which, there is another thing very confiderable in this periodical motion of thofe fecondary planets, and that is, that it is mixed with a kind of cochleous direction towards one or other pole of the primary planet; by which means every fatellite, by gentle degrees, makes its vifits towards each pole of its primary. This is well known among the Circumjovials, for inſtance, that they all have a ſlow and gradual ſcrew-like progreſs, firſt towards one, then back again towards the other pole of Jupiter; and that each ſatellite hath its declination greater and greater according as it is farther or farther from Jupiter's body. Accordingly the declination of each Circumjovial, aſſigned by the diligent and ſagacious Caſſini [k], after 12 years obſervations, are theſe. The greateſt declination of the firſt, or neareſt, exceeds not a third part of Jupiter's ſemidiameter: that of the ſecond ſurpaſſeth but a little of a quarter of its diameter: that of the third a little exceeds three quarters of the diameter; and that of the fourth, or outermoſt, goes beyond Jupiter's poles by a third part of the ſemidiameter. All which mutations, he ſaith, are performed in the ſpace of twelve years. Thus the famous Caſſini. But I have myſelf obſerved a greater vagation in the third ſatellite; that it advanced near to, if not even with the very limb or pole of Jupiter, and that its ſtay in Jupiter's ſhadow, or the duration of its eclipſe at that time, was leſs than is commonly aſſigned unto it, as it is reaſonable to imagine it ſhould be, becauſe the ſatellite had only the outſide of the cone of Jupiter's ſhadow, and

[k] *Les Hypoth. & Les Tables des Satel. de Jupiter*, § 4. in the French academiſt's large collection.

and confequently a leffer part thereof to pafs through at that time.

As to the end and ufe of this fo obfervable a tendency in the fecondaries towards each pole of their primaries, we may guefs at it from what hath been faid of the like tendency of the primaries towards the fun, on which our feafons do depend. So thofe fecondaries moving in like manner to each pole, effect fome of the grand works of the Divine Providence from pole to pole, illuminate all parts of their refpective globes, contract the length of their nights (as fhall be fhewn in a proper place) move their waters, and excite their tides, and perform other fuch great works of nature as, with good reafon, we attribute to the influx of our moon here in our own globe.

And can fuch well-contrived, fuch ufeful motions, that the world could not fubfift without, that nature could not do its grand works without, can thefe be other than the fiat of an infinitely indulgent, as well as wife Creator! Could this confonancy be fo univerfal, among all the globes that fall within our view? Could their periods and diftances be in the fame due proportion all the univerfe over, their motions all fo alike, had they

they not had the ſame contriver and maker! But I ſhall cloſe this argument with the reflection of the moſt ingenious Mr. Molyneux [1], who, ſpeaking of the ſeſquiplicate proportion of both the primary and ſecondary planets, thus concludes: "And from hence may we juſtly fall into the deepeſt admiration, that one and the ſame law of motion ſhould be obſerved in bodies ſo vaſtly diſtant from each other, and which ſeem to have no dependance or correſpondence with each other. This doth moſt evidently demonſtrate that they were all at firſt put into motion by one and the ſame unerring hand, even the infinite power and wiſdom of God, who hath fixed this order among them all, and hath eſtabliſhed a law which they cannot tranſgreſs. Chance or dull matter could never produce ſuch an harmonious regularity in the motion of bodies ſo vaſtly diſtant: This plainly ſhews a deſign and intention in the firſt mover. And with ſubmiſſion to the reverend and learned divines, I am apt to think that one argument drawn from the order, beauty, and deſign of things, is more forcible againſt atheiſm, than multitudes of notional proofs, &c." Thus Mr. Molyneux. But we ſhall find farther evidences of this ſupreme management in theſe matters from what follows in the next chapter.

[1] Diopt. Nov. Par. II. c. 6. ſect. 12.

CHAP. VI.

THE CONSTANCY AND REGULARITY OF ALL THE MOTIONS OF THE EARTH AND HEAVENS.

THAT the Earth and Heavens move at all, but eſpecially that they have ſuch particular and beneficial motions, appears, from the preceding chapters, to be the work of God. And the concurrence of the ſame infinite hand is as manifeſt in the perpetuity, conſtancy, and regularity of thoſe motions. For without this Almighty guide and manager, how is it poſſible that all thoſe vaſt and unwieldy maſſes ſhould continue their beneficial motions throughout all ages? Should perform their uſeful ſtages without any the leaſt intermiſſion, interruption, or diſorder that we know of? What motion, what contrivance, what piece of clock-work, was there ever under the whole Heavens, that ever came up to such a perfection, and that had not some stops or some deviations, and many imperfections? But yet none was ever so stupid as to conclude such a machine (though never so imperfect) was made by any other than some rational being, some artist that had skill enough for such a work. As he in Cicero [m] argues from his friend Posidonius's piece of watch-work, that shewed the motions of the Sun, Moon, and five erraticks; that if it had been carried among the Scythians or Britons, *Quis in illâ barbarie dubitet, quin ea sphæra sit perfecta ratione?* with more to the same purpose: no man even in that state of barbarity would make any doubt, whether it was the workmanship of reason or no [n]. And is there less reason to imagine those motions I have been treating of to be other than the work of God, which are infinitely more constant and regular than those of man! Or, to use the last mentioned Stoic's argument, can it be thought that Archimedes was able to do more in imitating the motions of the Heavens, (in his sphere) than nature in effecting them?

[m] De Nat. Deor. l. ii. c. 34.

[n] See the place cited at large in my Physico Theology, p. 2.

And now to reflect upon the whole, and fo conclude what hath been faid concerning thefe feveral motions; we may all along perceive in them fuch manifeft fignals of a Divine hand, that they all feem, as it were, to confpire in the demonftration of their infinite Creator and Orderer. For befides what, in all probability, is in other parts of the univerfe, we have a whole fyftem of our own, manifeftly proclaiming the workmanfhip of its maker. For we have not thefe vaft and unwieldy maffes of the Sun, and its planets, dropt here and there at random, and moving about the great expanfum, in uncertain paths, and at fortuitous rates and meafures, but in the completeft manner, and according to the ftricteft rules of order and harmony; fo as to anfwer the great ends of their creation, and the divine providence; to difpatch the noble offices of the feveral globes; to perform the great works of nature in them; to comfort and cherifh every thing refiding on them, by thofe ufeful changes of day and night, and the feveral feafons of the year.

Thefe things are fo evident to the reafon of all men, that Tully might well make his Stoic to alledge this as one of his principal arguments for

for the proof of a Deity *: "The fourth cause, saith he, and that even the chief, is the equality of the motion, and the revolution of the Heavens; the distinction, utility, beauty, and order of the Sun, Moon, and all the stars: the bare view alone of which things is sufficient to demonstrate them to be no works of chance. As if any one should come into an house, the Gymnasium, or Forum; when he should see the order, manner, and management of every thing, he could never judge these things to be done without an efficient, but must imagine there was some being presiding over them, and whose orders they obeyed. So much more in so great motions, such vicissitudes, and the orders of so many and great things;—a man cannot but conclude, that such great acts of nature are governed by some mind, some intelligent being.

And so again afterwards (Chap. 21) when, among other things, he had been speaking of the motions of the planets, he thus argues, "I cannot possibly understand, saith he, how all this constancy can be among the stars; this so great agreement of times through all eternity, among such various courses (how this can be) without

* De Nat. Deor. l. ii. c. 5.

ſome mind, reaſon, and counſel." And a little after this, ſpeaking of the fixt ſtars, he ſaith, "But the perennial, and perpetual courſes of thoſe ſtars, together with their admirable and incredible conſtancy, declare a divine power and mind to be in them. And this he takes to be ſo plain a caſe, that he that could not diſcern it, he thinks could diſcern nothing." And then he thus concludes, "In the Heavens then, there is neither any chance, nor any temerity, nor error, or vanity: but, on the contrary, there is all order, truth or exactneſs, reaſon and conſtancy. And ſuch things as are void, of theſe are counterfeit, falſe, and full of error.—He therefore that thinks the admirable cœleſtial order, and incredible conſtancy, on which the conſervation and good of all things depend, to be void of a mind, he himſelf deſerves to be accounted devoid of a mind." Thus with great force and reaſon, Tully's Stoic rightly infers the preſence and concurrence of a Divine Being and Power from the motions of the Heavens: only not being aware who that Being was, he erroneouſly imagines the heavenly bodies themſelves to have divinity, and puts them therefore into the number of the gods; which error is excellently refuted by Lactantius, in his Inſtit. Divin. l. ii. c. 5. &c.

BOOK

BOOK V.

OF THE FIGURE OF THE SEVERAL GLOBES OF THE UNIVERSE.

CHAP. I.

THE CONSONANCY OF ALL THE GLOBES IN THEIR SPHERICAL FIGURE.

HAVING in the preceding Book manifested the motions of the Earth and Heavens to be the contrivance and work of God, I shall enquire in this, whether their figure be of the same kind, wisely suited to the motions, and, in a word, to the whole state and convenience of the several globes, so as to manifest itself to be the work of God.

Now as to the figure; it is observable in the first place, that there is a great consent therein, among all the globes that fall under our view, and that is, that they are all ſphærical, or nearly ſo, namely, ſphæroidal [p]. Thus all the fixt ſtars, ſo far as we are able to behold them, either with our naked eye, or our glaſſes. Thus the Sun, and thus all its planets, and thus the ſecondaries, or Moons accompanying Saturn, Jupiter, and our Earth. And although Venus, Mercury, and our Moon have phaſes, and appear ſometimes falcated, ſometimes gibbous, and ſometimes more or leſs round, and even Mars too, in its quadratures, becomes gibbous: yet at ſuch times as theſe planets ſhew their full phaſes, they are found to be ſphærical, and only loſe this figure by virtue of their poſition to the Sun, to whom they owe their light. And this ſphæricity, or rotundity, is manifeſt in our Moon, yea, and in Venus [q] too: in whoſe greateſt falcations the dark part of their globes may be

[p] See Phyſico-Theol. B. ii. ch. 1. Note (w)

[q] What I have here affirmed of the ſecondary light of Venus, I have been called to an account for, by an ingenious aſtronomer of my acquaintance. But I particularly remember, that as I was viewing Venus ſome years ago, with a good 34 foot glaſs, when ſhe was in her perigee, and much horned, that I could ſee the darkened part of her globe, as we do that of the Moon ſoon after her change. And imagining that in the laſt total eclipſe of the Sun, the ſame might be diſcerned, I deſired a very curious obſerver that was with me, and looked through an excellent glaſs, to take notice of it, who affirmed that he ſaw it very plainly.

be perceived, exhibiting themſelves under the appearance of a dull and ruſty colour.

And as this ſphærical figure holds in every of the globes at a diſtance from us, ſo we may reaſonably imagine our own globe to be conſonant to the reſt. But indeed we have great reaſon to conclude it to be ſo from the curvity of its ſhadow in its eclipſes of the Moon; from the diſcovery of new conſtellations in the Heavens, as we change our hemiſphere, and make approaches towards either pole; from the ſurface of the ſea, which appears to be of this figure, by our gradually diſcerning far diſtant objects, mountains, towers, ſails of ſhips, &c. the parts of which are more and more ſeen, as we approach nearer and nearer to them: with other arguments to the ſame purpoſe, which I need not enumerate in a caſe now generally owned to be true,

CHAP. II.

OF THE INEQUALITIES, OR HILLS AND VALES OBSERVABLE IN THE EARTH AND MOON.

HAVING in the preceding chapter, demonſtrated the ſeveral globes of the univerſe to be ſphærical, it is not to be underſtood that theſe globes are ſtrictly ſo, but an allowance is perhaps to be made for the difference between their æquatorial and polar diameters, before ſpoken of; but eſpecially for thoſe little and inconſiderable excreſcences of the hills, very manifeſtly diſcernible in the Moon [r], as well as in our globe; which I call little and inconſiderable, eſpecially thoſe in the

[r] Every one that hath viewed the Moon with but an ordinary glaſs, eſpecially when ſhe is not round, may eaſily perceive conſiderable unevenneſſes; that ſome parts are manifeſtly higher, and others lower. About the quarters, divers bright golden ſpots may be ſeen in the ſhaded part, at ſome diſtance from the enlightened part; and theſe may be perceived to grow larger and brighter, as the ſhady parts turn more and more towards the Sun; till at laſt you may ſee all the intermediate valleys between thoſe ſpots and the other enlightened parts. Alſo in divers parts of the Moon, eſpecially ſuch

the Earth, becaufe they are fo in proportion to the Earth's diameter; as will appear by coming to particulars. The diameter of the terraqueous globe I have fhewn in my Phyfico-Theology [s] to be about 7935 Englifh miles, and in this book to be [t] 7967 miles:

fuch as border on the fhaded part, there may be obferved to be certain holes or pits, black, dark, or fhady, when the parts encompaffing them are illuftrious and bright. And this darknefs, as if under fome mountain, lies always on the fide next the Sun and gradually goes off, as the hole, pit, or valley turns more and more towards the Sun, till at laft the whole valley is enlightened, and looks like a depreffed ground in the body of the Moon. All which things are manifeft fignals that the Moon's furface is not even and fmooth, but like that of the Earth, full of hills and valleys.

Which opinion, although now well grounded on ocular demonftration, was as old or older than Plutarch's days, who in his book de Facie in orbe Lunæ, at the beginning, cites it as Clearchus's opinion Εικονας ισοπ'ριχως ειναι τα ειδωλα της μεγαλης θαλασσης, i. e. That what is called the Face of the Moon are the images and appearances of a great fea in the Moon. And about the middle of that tract, Το δε φαινομενον τυτι προσωπον—i. e. As to that face which appears in the Moon: as our Earth hath certain large bays; fo we conceive the Moon is overfpread with large hollows and ruptures, containing water, or a thick dark air into which the Sun-beams are not able to enter, and fo no reflection is made by them.

As to other matters in which the Earth and Moon feem to agree, as in fea, and great collections of waters, an atmofphere, &c. I fhall pafs them by here as improper for this place.

[s] Book ii. Ch. 2. Note (z).

[t] Book i. Ch. 4. Note (o).

miles: but that of the hills is no more than a few miles. Snowden in Caernarvonshire (the highest mountain in all our island) is but 1247 yards;[w] the Alps themselves but about two English miles[x]; nay, the very pike of Teneriffe, one of the highest ridges throughout the globe (unless we except the high mountains of Peru, called by Jos. Acosta[y] Periacaca;

[w] In the journal of the late ingenious Richard Townley Esq; of Townley in Lancashire, I find this note upon Sept. 6, 1682. This day Mr. Adams called here, who is taking a survey, &c. He told us, that with repeated trials he had found Snowdon-hill 1320 yards higher then the high-water-mark, and that the quick silver stood at the bottom at 29 Inches; at the top of the hill 25'96; so that 1320 gave 3'04. Then follows this note, viz. Mr. Adams coming since, tells me, that the height of Snowdon was but 1247 yards, which gave 3'04.

The reason of this difference of 73 yards, in the height of Snowdon, I take to be, that the first measure was made by Mr. Adams himself, the latter by Mr. Caswell, with Mr. Adams's instruments: and probably the former is the height above the sea, the latter only above some plane.

[x] Mr. Nich. Facio told me, that he had measured the height of the Montagne Mauditi, which is one of the highest ridges of the Alps, and that he found it to be 2000 French toises above the Lake of Geneva, which is equal to 12816 English feet, or 2'42 miles.

[y] Acosta saith, the Alps seemed to these mountains he travelled over, but as ordinary houses to lofty towers. See my Phys. Theol. B. 1. Ch. 1. Note (w).

Capt.

Periacaca: or that near St. Martha [a]; or those called the Andes [a];) this ridge, I say, is computed to be but between three and four miles perpendicularly above the sea [b]. All which eminences, compared with the diameter or semidiameter of the earth, is no more than as a particle of dust to a large globe on which it resteth.

And so likewise for the mountains visible in the Moon, although some of them are of that height [c] as to reflect the light of the Sun from their lofty tops,

[a] Capt. Dampier saith, that he is of opinion that the hill near St. Martha is higher than the pike of Teneriffe. See Voyage round the World, p. 24.

[a] Of the Andes of Chili and Peru, Capt. Dampier saith, these are the highest mountains I ever saw, far surpassing the pike of Teneriffe, or Santa Martha, and I believe, any mountains in the world. Ibid. p. 93.

[b] See Dr. Hooke's account of the pike of Teneriffe, from his friend Mr. G. T. who went to the top of it; at the end of his lectures concerning springs, p. 42.

[c] By Riccioli's measures, the height of what he calls Mount Sinai, or St. Katharine's Hill, is nine Bononian miles, and that of Xaverius 11; but according to his corrections, the former is but $8\frac{14}{23}$ miles, the latter $11\frac{1}{4}$. Which at the rate of 6020 English feet in a Bononian mile, is about 13 and 9 English miles; an height so great, considering how much the moon is less than the Earth, that I can-

I cannot but think that diligent perſon was miſtaken in his meaſures, and that the computations of Hevelius are much the beſt; who, as he was as able as any man, and made more accurate and diligent obſervations of the Moon's face, than moſt men ever did, ſo he was more likely to come neareſt the truth. And by his reckoning, the higheſt hills in the moon are but about three quarters of a German mile, and ſome of them but ſeven ſixteenths, and ſome not above an Italian mile. And conſidering the bulk of the Moon to that of the Earth, theſe are great eminences for the Moon.

And as the lunar mountains are of ſuch prodigious heights, ſo many of them are of great extent. Hevelius reckons the Lunar Taurus to reach to 170 German miles; Mount Sepher 150; and the Lunar Appenine about 100 German miles.

The way how to meaſure the height of the mountains of the Moon is not difficult, nor uncertain; which is, by obſerving the diſtance between the diſtant golden ſpots, at their firſt appearance (which are the tops of hills) and the enlightened part of the Moon. Which diſtance may be computed by miles, or any other equal parts, into which we can imagine the moon's diameter divided. Thus in Fig. 5. A R B is a part of the Moon's circumference, one part of which A R is enlightened, the other part R B is in darkneſs. H i is a mountain, whoſe top H is touched by the Sunbeams, ſhining from S the Sun to R, and reaching to H. Now ſuppoſing the ſemidiameter of the Moon, R C, to be 274 German miles, according to Hevelius, the length of the ſide R H (or diſtance between the top of the hill, and the edge of the enlightened part) will be found alſo to be a 10th, 20th, or other part of that ſemidiameter or diameter; or ſome certain number of miles. And then we have the two ſides R C 274 miles, and R H, and the right angle included between them; by which, both the other angles, and the ſide C H, may be found by a common caſe of right angled triangles. Out of which ſide C H, deducting the Moon's ſemidiameter 274, there remaineth the height of the mountain H i. Conſult here Hevel. Selenogr. Ch. viii. Galilæus Nunc. Sider. p. 53. Riccioli Almageſt. L. iv. c. 8. Schol.

tops, ſome days before ever it reacheth the valleys beneath them, yet on the Moon's limb we can diſcern nothing of them: but ſo far from that, that, on the contrary, the edge through our beſt glaſſes looks like an even, ſmooth, and uninterrupted circle [d].

Although then vaſt mountains, when ſeen near at hand, ſeem to be very conſiderable excreſcences of our globe, yet ſince they are little, when com-

[d] The edge of the Moon, which I here mean, is that next the Sun; on which I could never perceive with my beſt glaſſes any the leaſt ſign of a mountain, but all to be exactly level and ſmooth. Only indeed there are ſome certain tranſient roughneſſes and unevenneſſes on the limb cauſed by vapours, eſpecially when the moon is near the horizon, and in windy, and in ſome other weather. At which time the motion of the air and vapours makes a pretty criſpation and rolling, like waves, on the Moon's limb, which have the appearance of moving mountains and valleys. But on the oppoſite ſide, if the leaſt portion of the darkened part of the Moon extends beyond the enlightened part, mountains may very manifeſtly be diſcerned, exactly reſembling ours on the Earth. A few hours before and after the full, I have with pleaſure ſeen the appearance of conſiderable mountains and bays. One of which views I have given in Fig. 6. which is the Moon's appearance, ſoon after the full, on Sept. 12, 1714. In which ſeveral riſings and depreſſions may be ſeen, and the tops of ſome of the mountains ſomewhat diſtant are expreſſed by the little ſpots.

Theſe alone I conceive are mountains which the excellent Hevelius ſpeaks of in ſeveral places of his Selenography, particularly in his anſwer to Bettinus, and other Peripateticks, in Ch. vi. p 143. who denied that mountains could be in the Moon, as well as many other things diſcovered now by the teleſcope.

compared to the globe itſelf, we may look upon our own, and all the reſt of the globes, as if they were perfect ſpheres, or at leaſt ſphæroids. And finding them to be ſuch, let us next enquire what reaſon there is to imagine this their form to have been the great Creator's work.

CHAP.

CHAP. I.

THE UNIVERSALITY AND UNIFORMITY OF THE FIGURE OF THE SEVERAL GLOBES OF THE UNIVERSE, IS A SIGN OF THEIR BEING THE WORK OF GOD, NOT OF CHANCE OR NECESSITY.

WHEN we fee divers pieces of curious device and workmanfhip to bear the fame marks of art, to have the fame mafterly ftrokes of painting, clockwork, architecture, &c. we conclude, with great reafon, fuch pieces were made by the fame fkilful hand. So when we fee the fame commodious fphærical figure to be imparted to the Earth, and all the heavenly bodies, we have as good reafon to conclude them to be pieces of the fame hand, contrivances and works of the fame fkilful architect. For if the univerfe had been a work of chance, all the feveral globes would have been of feveral forms, one of this, another of a quite different figure: one fquare, another multangular, another long, and another of another fhape. Or if all the ſeveral globes had been a work of neceſſity, and their figure had been owing to the natural tendency, or gravity of matter, viz. that the ſelf-attracting power of matter did make all the ſolids and fluids of all the ſeveral globes, as naturally run into a globoſe form, as a drop of quick-ſilver doth: yet ſtill we may demand, how came matter by this ſo commodious a power: What made it affect ſo proper a form, but the infinite Creator's fiat?

But not to conteſt that point, but granting gravity to be congenial and coeval with matter, without enquiring how it came by that power, and allowing that every globe in the univerſe had its form from the ſelf-attracting power of its matter, yet ſtill we have undeniable marks of final cauſes, of wiſe order, and an over-ruling power in the caſe. For let us imagine our terraqueous globe in the chaotick ſtate; all its matter, every particle of it divided, and floating about, and ready by its ſelf-attraction to run together into its natural form, that of a globe: In this hurly-burly, this jumble of unguided nature made by attraction only, a confuſed globoſe maſs can be ſuppoſed to be formed; but

without

without any order, without that convenient lodgment of its parts, as the neceſſities of an habitable world require. But inſtead of any ſuch ſigns of diſorder, or of nature's acting with an unguided power, we have the clean contrary; all ſignals of a wiſe contrivance, and excellent art; as will appear in the following Chapter.

CHAP. IV.

THE TERRAQUEOUS AND OTHER GLOBES APPEAR TO BE THE WORK OF GOD, FROM THE WISE DISPOSITION OF THEIR PARTS.

AS the Earth, and all the other globes, would have been of various forms, if they had been made by chance, or would have been confused masses, if made by necessity, according to the last Chapter; so in this I shall shew them to be the work of a wise and a kind agent, from the commodious structure and disposition of their parts, so far as we have any knowledge of them. Thus the Moon hath great appearances of being no less commodiously than the Earth, divided into hills and valleys, (as I have set forth in the second Chapter) into dry lands, and great collections of waters [e], and to be encompassed with an

[e] That there are seas, or great collections of waters in the Moon, is highly probable from the Moon's spots, which plainly seem to be water on these two accounts: 1. Because those spots appear to be in strait and level long planes, when viewed about the Moon's quarters, or

an atmosphere as we are[f]. So Jupiter, although at so great a distance from us, hath manifestly, we see, his lighter and darker parts; his belts and spots

at such times as one half of them are enlightened, the other half in darkness. In this case, when we do not look directly upon the planes, or see them wholly enlightened, but view them in a manner side ways, their surfaces look as the sea doth when we view it from the shore, viz. a large level plane: only we may now and then discern a bright shining part standing a little out of the large levels, which are, no doubt, certain rocks or islands in the midst of those seas: 2. The darkness of those spots more than other parts of the Moon is an argument they are water, or some such like fluid, which imbibes the Sun's rays more than harder bodies, and doth not therefore so vigorously reflect them as they do. Accordingly about the Moon's quarters, when those spots, as I said, have the appearance of long planes, we may observe their edge to be a kind of hazy border, which grows darker and darker, as the rays are more and more absorbed.

But indeed hard bodies, if they have smooth surfaces, although they reflect strongly to one place, yet in other places they are less visible. Thus a looking-glass, a diamond, &c. reflect vigorously the sun's rays towards one part, so as to dazzle the eyes; but in other parts they appear of a dark, blackish hue. Which, by the bye, is the reason why jewellers grind their diamonds with many sides and angles, that their lustre may appear many ways. So silver (as Galilæo observes, Dial. 1.) when boiled only in argol and salt, appears as white as snow; but wherever it is burnished, it becomes obscure. And so he tells us, rightly enough, the Moon would become invisible to us, if its surface was not rough, but sleek and smooth. See also Hevelii Selenogr. chap. vi. p. 151.

f That there is an atmosphere about the Moon, see Book vii, chap. 3. Note 1.

ſpots darker than the reſt of his diſk. Theſe Mr. Caſſini (who longer viewed this planet than any body elſe) takes to be canals containing ſome fluid matter, or water, that more weakly reflects the ſun's rays than the other parts of the planet do, and that they have ſome reſemblance with what happens here upon earth [h], "For if," ſaith he, "one from on high in the heavens ſhould ſee the earth in ſome particular ſituations, the ſea which encompaſſeth the earth would appear very like the great ſouthern belt that encompaſſeth the whole globe of Jupiter: the Mediterranean ſea would make an appearance not unlike thoſe belts which are interrupted or broken, which we ſee in this planet: the other ſeas would make thoſe great black ſpots which never alter at all: the continents and iſles would ſeem like thoſe bright ſpots that are alſo permanent; the ſnows would make thoſe glittering ſparkles [brilliants] that from time to time diſappear: the flux and reflux of the ocean, and thoſe great inundations that happen ſometimes here, would occaſion other ſpots to appear and diſappear: the moon would reſemble one of Jupiter's ſatellites: in fine, the clouds of our atmoſphere would reſemble thoſe broken

[h] Nouvelles Decouvertes de Jupiter; par M Caſſini, in the Memoirs de Mathem, & de Phyſique for Jan. 1692.

broken interrupted belts, and thofe tranfitory fpots, which often change their fize and figure, and have motions of different velocities."

Thus that ingenious and curious obferver: according to whofe not improbable opinion, this planet Jupiter hath all its parts orderly placed, as is here upon earth.

And fo for the reft of the planets, whofe faces exhibit different appearances of brighter and darker parts, as Mars and Venus particularly do[i], it is highly probable, that thefe may be fuch a diftribution, fuch an allotment of parts, as thofe in Jupiter, and which are more plainly vifible in our own globe.

Which brings me to fpeak particularly of our own globe, of which we have a nearer view, and can plainly fee the foot-fteps of Divine Providence in the wife and orderly difpofition of all its parts: which are fo diftributed, fo placed, as may beft minifter to the feveral ufes and conveniences of an habitable world. Thus, for inftance, the two grand parts, the folids, and the fluids of the terraqueous globe, inftead of being

[i] See Book IV. Chapter iii.

jumbled into one mass, are admirably parted, and as nicely laid in proper places. The earth deposited in useful strata; some for the service of the vegetable kingdom; some for the generation and nourishment of minerals and metals; some for that of stones and fossils; and some for the sweetening and conveyance of the waters. And here it is remarkable, and an argument of a wise design and appointment, That all those several strata, or beds, are lodged at proper and convenient depths and distances from the surface; that for vegetables, the uppermost, for every man to cultivate; and this divided into various soils and moulds for all the varieties of trees and plants; those strata that contain the minerals, metals, and fossils, at such depths, as to be out of the way, when they may encumber or hurt us, but may be come at by us, when we have occasion for them: and as for those strata that convey the sweet waters [k], it is very remarkable, that they are so universal, in all, or most parts of the world, that they consist of such proper pervious matter; that they remain so distinct from, and unmixed with the other strata; and that they lie at such due depths, as either to break out in fountains, or to be dug into, for wells. But I shall

[k] See Physico-Theol. B. iii. Chap. 2.

ſhall not enlarge on theſe matters, having ſpoken of them elſewhere.

And as this ſo commodious a diſtribution of the earth, ſo that of the waters is a manifeſt demonſtration of the concern of a wiſe agent, although we ſhould aſcribe all that is poſſible to be aſcribed, to the neceſſities of nature in the formation of the world. For the waters, if we obſerve them well, are accurately diſperſed and lodged about the world for the proper offices thereof; in ſeas, in lakes, in rivers, and in fountains, to ſatisfy the thirſt of animals, to afford them ſome part of their food, and to miniſter abundant ſupplies of vapours for the clouds, the rains, and winds: which ſupplies muſt either have failed, or been too abundant, or have been attended with ſome or other great inconvenience, without ſuch a commodious intermixture of the land and waters.

This Συναγωγὴ, as the LXX tranſlate it, this orderly gathering together of the waters, is implied in Moſes's relation of this branch of the creation, Gen. i. 9. "And God ſaid, Let the waters "under the Heaven be gathered together unto "one place." Where the Hebrew word Ikkavu, denotes a regular and orderly gathering of the waters,

waters, as if their allotment had been made, their receptacles had been marked out by a rule, or a plumb-line, by the Creator's fiat,

Thus it is demonſtratively plain, that the earth and waters were laid by a wiſe hand; and therefore whatever concern nature might have in giving a ſphærical figure to our globe, yet was the Creator the principal agent, the grand manager of the matter.

CHAP.

CHAP. V.

THE CONVENIENCE AND NECESSITY OF A SPHÆRICAL FIGURE TO THE GOOD OF THE GLOBES, IS AN ARGUMENT THEY WERE THE WORK OF GOD.

BESIDES the orderly and commodious placing the parts of the ſeveral globes ſpoken of in the laſt Chapter, there are ſtill other reaſons to aſcribe the ſphæricity of our own and the other globes to a wiſe agent. For beſides that this figure is the moſt agreeable to a world, as being the moſt capacious; and the moſt agreeable to a maſs in motion, as being at a due diſtance from the center of motion and gravity; ſo without this figure there could have been no ſuch comfortable and agreeable alterations of day and night, of heat and cold, as now there are, but ſome parts muſt have been for too long a time ſkreened from the kindly approaches of the ſun and moon, and conſequently have lain under too long and uncomfortable a darkneſs, and been chilled

chilled with miserable cold. And as to our own globe, the winds could not have given those kindly and salutiferous agitations to the air as they do, but they must have been too much retarded, if not wholly stopped by the exorbitant angles and jettings out of other figures. And, lastly, the waters which I shewed to be well intermixed with dry land, would have had intolerable confluences; one part too much, another none at all; no vapours, no fountains, no rivers: so that instead of an habitable, well-stocked world, far the greatest part would have been either a desart, or an unnecessary confluence of water.

Thus having made it evident, that particularly our own globe received its figure by the direction of the infinitely wise architect of all things: we have reason, had we none besides, to conclude the same of all the rest of the globes of the universe, inasmuch as they agree with ours in other things as well as in their figure, so far as we have any knowledge of them, and their state. Thus the planets of the Solar system have their light from the sun as well as we; they turn round on their own axes, and revolve round the sun, and consequently have their days and nights, their summers and winters, as well as we: they have

have their hills and valleys, as I ſaid, their land and waters, by all the ſigns that may be, as well as we; and therefore agreeing with our globe in ſo many of thoſe very things, wherein their figure is concerned, had we none of thoſe reaſons I have already mentioned, there would however be great reaſon to preſume the ſame thing of them, as of our earth, viz. That they received their figure from the ſame wiſe Creator, and that (were we near enough to behold them) they have as manifeſt ſignals of it as we have.

BOOK VI.

OF THE ATTRACTION OR GRAVITY OF THE Terraqueous and the other Globes.

CHAP. I.

THE USEFULNESS OF ATTRACTION IN THE PRODUCTION AND PRESERVATION OF THE FIGURE OF THE EARTH, AND THE DESCENT OF HEAVY BODIES.

HAVING in the two laſt books treated of the motions and figure of the globes, I ſhall in this conſider their gravity or attraction, which according to the modern Philoſophy, (which hath great reaſon and probability on its ſide) hath a great agency in both theſe matters, both in effecting and preſerving the figure of the globes, and governing their motion.

As

As to the agency of the natural attraction of matter in the production and preservation of a sphærical figure, as that of the several globes is, besides what hath been before supposed, it may be collected from the sphærical figure which most fluids take, when there is no obstacle to hinder their doing so. Thus I have said quicksilver manifestly doth, especially in small drops or quantities; in which case their own self-attracting power is equal to, or exceeds that of the earth: so doth lead and other metals when in fluxion [1]; so doth water, oil, and in short, all liquids, which run nearly into a sphærical form, when hung on a small surface; as at the point of a pin; or into an hemisphærical figure, on a broader surface; their self-attraction causing the former, as that of the earth and the surface on which they lie, doth the latter. These phænomena have indeed been ascribed to divers causes, most of them probable enough, except the pressure of the incumbent air; but this is manifestly not the true cause, by reason the case is the very same

[1] This is very manifest from the making of shot. The way of doing which, is by running the melted lead through a ladle full of holes into cold water. In doing which they take care their lead be not too hot, because the globules would then fly to pieces; nor too cold, because it would then be long and have tails; but in a due temper it turns round. They put orpiment into their lead, when they melt and prepare it for shot.

fame in the air-pump (when the preffure is taken off) as in the free air; and therefore fome other caufe is to be found: and what more probable, or fo probable as this of gravity or attraction, which manifeftly exerts itfelf in fome, and is highly probable in all material things[m]? In the earth itfelf there is manifeftly fuch a thing as gravity, which might as well be the natural caufe of the fphæricity of our globe, as it is in that of leffer maffes; but then, as I demonftrated in the laft book, it is alfo evident, that an over-ruling Power, and a wife Providence, not only gave matter this gravitating power, but guided and managed it in the formation of the world.

And now upon fuppofition that gravity had any thing to do in the production of this fphærical figure I am fpeaking of, the fame it muft have alfo in the confervation of that figure. For the fame power it exerted at firft, it retains ftill; which is as neceffary ftill to the preventing and obviating all extravagant excurfions, and deviations from that figure which may happen through extraordinary

[m] For the proof of this, I fhall refer to Sir Ifaac Newton's Opticks, Queft. 13. of the fecond edition, and in his Principia, in many places, particularly l. iii. Prop. 5, 6, 7.

extraordinary commotions and convulſions in any of the globes; ſuch as earthquakes are, and other ſuch like furious concuſſions and emotions that ſometimes befal our own globe.

But leaving theſe conjectural matters, let us come to a more evident benefit of gravity, and that is the natural tendency of all bodies to the centre of the globe: this is very manifeſt in our own globe. For whatſoever the decays are among earthly things, howſoever their forms are changed, yet their matter remaineth entire, and returneth again to its grand parent the earth: or, to put it in Solomon's words, Eccl. i. 4. "One "generation paſſeth away, and another genera-"tion cometh: but the earth abideth for ever.

And an admirable proviſion this is for the perpetuity of the globe, and to continue the ſtate and habitability thereof throughout all ages, which would otherwiſe waſte and decay, or run into the moſt irreparable and pernicious diſorders.

CHAP. II.

THE GUARD WHICH GRAVITY AFFORDS AGAINST THE CENTRIFUGAL FORCE OF THE SEVERAL GLOBES.

UPON a ſuppoſition that every of the globes revolves round its own axis, (which I have ſufficiently proved in the fourth book) we ſhall find, beſides the benefits already ſpecified, another very great uſe of gravity to the good, yea, the very exiſtence of our own and other globes, and that is the preſervation of their integrity againſt the centrifugal force of this their revolution or diurnal motion. For without ſuch a band, as gravity, to keep their parts together, the whirling about of thoſe globes would ſhatter them into pieces, and diſſipate them abroad into the circumambient ſpace. Thus muſt it needs befal our own globe, which whirls about at the rate of above 1000 miles

miles an hour [n], and is composed of earth and water, materials of much too loose a texture to prevent the dissipation which the centrifugal force of such a rotation must necessarily occasion about the æquatorial parts, a rotation that would as easily throw off the parts of the earth, especially the waters, as the whirling round of a wheel or a globe, would the loose dust and water lodged thereon. But by reason the gravitating power exceeds the centrifugal as 2174 exceeds 7'54064 [o], that is above 288 times; therefore all parts lie quiet and secure in their respective places, and enjoy all the benefits, which I shewed do accompany this motion without any disturbance from it.

Thus is our own globe guarded by its gravity against the centrifugal force of its rotation. But this is far more remarkable in some of the other globes. Thus particularly in the sun, whose ambit is 2582873 miles, and whirls round once in

[n] The diameter of the earth being 7967'7 miles, according to b. i. chap. 2. note 1. the Ambit thereof is 25031'4 miles, which being divided into 24 hours, makes the revolution to be at the rate of 1043 miles an hour.

[o] This is the proportion, or nearly so, of the gravitating to the centrifugal force of the earth under the equator, as may be computed from Sir Isaac Newton's Princip. l. iii. Prop. 19.

in about $25\frac{1}{4}$ days, and consequently doth revolve at the rate of 4262 miles an hour [p], which is above four times as fast as the earth; this in a little time would endanger its dissipation, without such a provision as gravity is.

But what is this to the centrifugal force of Jupiter? whose bulk far exceeds our terraqueous ball, and whose rotation is performed in less than half the time. But from a computation of particulars we shall better estimate the matter. The diameter of Jupiter being 120653 miles, its circumference is 379043 miles: which revolving round in less than ten hours, is at the rate of 38159 [q] miles an hour at its æquator. And if the

[p] The Sun's diameter being 822148 miles, the numbers here assigned will naturally follow.

As to the Sun's gravity or attractive power, it is (by the calculation of my friend, the acute and learned Dr. Halley) to the Sun's centrifugal force, as 47000 to 1: the method for finding which, see note (r) p. 223.

[q] Jupiter's ambit being 379043 miles, and his revolution 9 h. 56′, or 596 minutes; the revolution in an hour is, by the logarithms, thus:

596 minutes	2.7752463
379043 miles	5.5786684
::60 minutes	1.7781513
	7.3568197
38159 miles	4.4815934

the denſity of every planet be proportional to its diſtance from the ſun, as is now with great reaſon imagined, that is, if thoſe planets neareſt the ſun, as Mercury and Venus, are proportionably denſer than thoſe more remote, as Jupiter and Saturn; then is the globe of Jupiter of a laxer texture than ours is, and in ſo much the greater danger therefore of being whirled to pieces by ſo rapid a motion as that planet manifeſtly hath, were not its parts kept cloſe together and ſedate by ſuch a band as gravity [r] is.

[r] The proportion of Jupiter, or any other planets, or the ſun's gravity, to their centrifugal force may be computed from the moſt ſagacious Sir Iſaac Newton's Princip. l. iii. Prop. 8. & 19. But the before-commended Savilian profeſſor ſuggeſted to me this eaſier and quicker rule, for ſuch planets as have ſatellites, viz. The proportion of the centrifugal to the centripetal force, or gravity of any planet at its ſurface, is compounded of the ratio which the cube of the ſemidiameter of the planet hath to the cube of the diſtance of any of its ſatellites from the centre of that planet; and the ratio which the ſquare of the ſatellites periodic time hath to the ſquares of the periodic time of the planet's revolution. Thus for inſtance, the diſtance of Jupiter's outermoſt ſatellite being 253 ſemidiameters of Jupiter, and its period 16 days, 16 hours, 32 minutes, or 24032 minutes, and Jupiter's revolution 526 minutes; we ſhall find the gravity in Jupiter's ſurface to be to his centrifugal force in his aequator, as 1 to 9'96.

CHAP. III.

OF THE POWER AND USEFULNESS OF GRAVITY TO RETAIN THE PLANETS IN THEIR ORBITS.

FOR a conclusion of this sixth book, I shall take notice of one more remarkable benefit of gravity, which is grounded upon the supposition of the truth of the Newtonian philosophy; which hath so good grounds, and great reason, I might say demonstrations on its side, particularly in this matter, that, admitting of it here, we shall discover another admirable work of the creation, and that is, the preventing the evagation of the planets, and the accurate retaining them within the due bounds of their orbits. That this is done by gravity, and that gravity and motions solve in the most complete manner, all the phænomena of the planetary motions both primary and secondary, is abundantly made out by the wonderful sagacity of the great Sir Isaac Newton; as may be seen in his Principia.

But

But before I come to the particular agency of gravity, it will be neceſſary to premiſe ſomething concerning its nature, and ſome of its properties, viz. That gravity is not terminated at the ſurface, but reaches to the very centre, and is extended to immenſe diſtances all round the centres of all the globes: by which means the cœleſtial bodies are enabled to have ſyſtems of leſſer globes revolving about them. For had the force of gravity determined at, or near the ſurface, (as it might have done, if intended only for the conſervation of the globes) in this caſe, all the bodies that were put in motion, and that were to paſs at ſome diſtance from them, would move on in a ſtrait, not curved line, and be loſt in the great abyſs of ſpace. But the all-wiſe Creator hath, in his firſt production of matter, beſtowed upon it ſuch a property, as that every particle thereof hath a tendency towards every other particle. From whence it comes to paſs, that every body hath a gravitating power, according to the ſolid content or real quantity of its matter, and not according to its ſuperficies, or extenſion.

And this gravity of all bodies is obſerved, manifeſtly to decreaſe in proportion of the ſquare of their diſtances reciprocally; that is, at twice their diſtance the force is but one fourth of what it was at a ſingle diſtance; and but a ninth at thrice the diſtance, &c.

That this is ſo, is abundantly proved by the laſt commended author; who, by eſtabliſhing this one principle in philoſophy, hath fully explained the ſyſtem of the world, ſo far as relates to us, and to all the reſt of the planets, that regard the ſun as a centre, both primary and ſecondary.

What the cauſe of gravity is, Sir Iſaac Newton doth not pretend to aſſign, his deſign being not to engage himſelf in framing hypotheſes, but to explain the phænomena by experiments only, and to raiſe his noble ſuperſtructure upon them. And therefore, although the matters of fact, and the final cauſes are evident, I will not venture to ſay how it came to paſs, that bodies act at ſuch immenſe diſtances upon one another; but chuſe rather to acquieſce in adoring the wiſdom and power of the Great Author of all things, who hath inſpirited the materials of which the world conſiſts, with ſuch an active quality, as ſerves not only to preſerve the globes themſelves entire, but to enable them to revolve about their luminous centre (from whence they have their

their light and heat) in orbs that are the moſt commodious, and alſo fixt and permanent.

Having thus premiſed what was neceſſary for the underſtanding the nature and properties of gravity, I ſhall proceed to conſider its agency in the planetary motions. And here we have divers things, which plainly demonſtrate theſe motions to be no matters of chance, but the works of an infinitely kind, as well as omnipotent and all-wiſe Agent.

I have already in book iv. chap. ii. taken notice of the motion of the planets being made, not in lines tending from the centre to the circumference, or very obliquely thereto, but acroſs, or nearly perpendicular to the radii. Alſo that the motions and orbits of the planets do not tend contrary ways, or interfere with one another. That therefore which I ſhall ſpeak of here, concerning the planetary motions being the work of God, will be only ſo far as gravity is therein concerned. And,

1. It was a very notable proviſion to prevent the evagation of the planets, and keep them within their due and proper bounds, to bridle and detain them with gravity, as with ſo many reins and

and bridles. For as the natural tendency of all impreſt motion is in ſtrait lines, ſo when motion was given to the planets, this motion (although as I ſaid it was artificially made, perpendicularly to the radii, yet) would carry them quite away in their tangents, ſo that they would never return again. But being thus detained by gravity, another admirable proviſion is, that, 2. They are moved in orbs: which orbs are formed of a motion compounded of this rectilinear impulſe, impreſt upon the planets, and the tendency of their gravity to the centres. In which motion a third thing very remarkable is, That the impulſe or velocity which is imparted by the firſt mover to every planet, and the gravity of each planet, are ſo nearly equal to what is required to make a body deſcribe a circle, that the orbits of the planets are not very eccentrical, but nearly circular. As is particularly remarkable in Venus, and the earth; and more eſpecially in the whole ſyſtem of Jupiter's ſatellites. And an admirable work this is, For ſhould the velocity of any planet be double to what would make it move in a circle, the planet would go away *in infinitum*, without ever returning again in any orb whatſoever. Or ſhould one half of the velocity be taken away, the planet would deſcend obliquely towards the ſun, until it became four times nearer the

the ſun than before; and then aſcend again to its former place, deſcribing a very eccentrical orb. And by aſcending and deſcending alternately, it would be heated ſixteen times more at one time than another. Which uneven heat would make the planet unfit for habitation. And the ſame thing would happen, if the determination of its motion ſhould be altered, ſo as to become very oblique to the radius drawn from the planet to the ſun. But theſe things being accurately adjuſted, and contempered, make the whole ſyſtem to be a work of incomparable convenience and beauty; a work the beſt contrived for the benefit of the world's inhabitants, and to ſet forth the curioſity and ſkill of the infinite Workman.

It is manifeſt therefore that the ſyſtem of the planets is not to be reckoned a matter of chance, or a thing owing to a neceſſity of nature, but the work of a kind and wiſe Agent. And that this is ſo, will be farther manifeſt from the caſe of comets, whoſe motions, directions, and orbs, being utterly different from thoſe of the planets, demonſtrate the planetary ſyſtem to have been modeled by counſel, and not by a neceſſity of nature, or left to chance. For as for the motion of comets, it is ſo far from being always the ſame way, that they move ſometimes contrary to one another.

another. And as for their planes and directions, they lie every way. And as for their orbs, they are exceedingly eccentrical. And by the bye this eccentricity is an admirable contrivance of the Creator, to prevent the comets from disturbing either the planets, or one another, by their mutual attractions. For by this means, they have a large and sufficient room to revolve in; and by ascending to very great heights above the system of the planets, and spending almost all their time in the remote regions of the universe, at vast distances both from the planets, and from one another, they do not incommode either the planets, or themselves; as otherwise they would have done, should they have moved in the same plane with the planets. For had they done so, they would have been apt sometimes to have come too near the planets and have disturbed their motions, and perhaps have dashed upon them also. But all these circumstances are so well adjusted, and so wisely regulated by the Divine Providence, that the system could not have been better contrived, either for convenience or beauty.

And now upon this highly probable, I might say physically certain, theory of gravity acting in the motion of the globes, we have another exquisite

quisite nicety in the works of the creation, that justly deserves the greatest admiration and praise; that among so many immense moving masses, they should all observe their due bounds, keep the most proper paths appointed for their convenience and good, and at all times answer the great ends to which they minister in the creation. Particularly, that the habitable globes should always remain at such due distances, and move in such proper orbits, as are best for them. And that the comets too, should at the same time pass in paths utterly different, but yet such, in all probability, as may render them also of very great use to some or other parts of the world; whether we look upon them as places of torment (as hath been said) or bodies appointed for the refreshment and recruit of the sun, or any of his planets, as Sir Isaac Newton conjectureth in his Principia, l. iii. Prop. 41, & 42.

And now from the consideration of what I have shewn in this sixth book, to be either highly probable, or very certain concerning gravity, we have another manifest demonstration of the infinite Creator's wisdom and care, and another cogent argument to excite the highest veneration and praise in his creatures.

BOOK VII.

Of the PROVISION made for LIGHT AND HEAT THROUGHOUT THE UNIVERSE.

CHAP. I.

OF THE LIGHT AND HEAT OF THE FIXT STARS AND SUN.

AS light and heat are two of the moſt uſeful things in the univerſe, ſo the infinitely wiſe and kind Creator hath made an excellent proviſion for theſe things, in all probability for every globe throughout the univerſe, but particularly for thoſe of our own ſyſtem. For it is very manifeſt that every globe we ſee, doth ſhine with its own native, or with borrowed light. Even all thoſe immenſe bodies at the greateſt diſtance from us, the fixt ſtars, which, I have before ſaid, are

are probably ſo many ſuns, it is light they manifeſtly dart as far as to our ſo diſtant globe, as well as what they emit for the enlightening, warming, and cheriſhing their own reſpective planets.

But I ſhall forbear to launch out into thoſe conjectural matters, and ſhall come nearer home into our own ſyſtem, where we have enough to entertain our eye, to captivate our thoughts, and to excite our higheſt admiration of theſe magnificent works of God; whether we ſurvey the great fountain itſelf of our light and heat, the ſun; its due poſition, and its wonderful uſe to its planets; and the incomparable proviſions that are made to ſupply its abſence and greater diſtances from them.

And in the firſt place, as to the ſun itſelf; what power is there that the moſt extravagant fancy can imagine to itſelf, that could ever be able to make ſo prodigious a maſs of fire as the ſun is, but only the power of God's almighty hand! a body of ſo immenſe a bulk as I have ſhewn it is, and of ſuch an exceſſive heat, that no greater number of its rays than what fall within the compaſs of a two or three inch burning glaſs, ſhall actually burn; and what fall within the compaſs of not many feet, ſhall far exceed the ſtrongeſt culinary fire in the earth; as is manifeſt from its almoſt inſtantaneous burning, and vitrifying the moſt obdurate incombuſtible bodies, ſuch as not only green wood, and white bodies, but alſo ſtones, bricks, metals, yea gold itſelf (the hardeſt of all metals to be wrought upon by fire) which yet is melted down in a few minutes [a].

Thus the infinite power and wiſdom of God appear in the appointment and make of that immenſe

[a] The famous burning-concave at Lyons of 30 inches diameter, and others in France and Germany of greater breadths, have been celebrated for their feats in burning, calcining, and vitrifying both metallick and other bodies. But I queſtion whether any of them have come up to the burning inſtrument contrived by, and made for Sir Iſaac Newton, and by him preſented to the Royal Society. It conſiſts of ſeven concave foiled glaſſes, each of them 12 inches diameter, which are all ſo placed as to have their foci concur in one point. By which means the heat is ſo increaſed, as in a ſurpriſing manner to perform the feats here mentioned, and many others ſurpaſſing them.

Having mentioned theſe burning-concaves, it may be of uſe on ſeveral occaſions, and particularly for the cheap trying of experiments, to take notice of what was related to me by a perſon of very high quality: who doing me the honour to talk with me about ſuch concaves, told me, that in Germany one Mr. Czhernhauſen, a Sileſian gentleman, made divers very large concaves with paſteboard; which were covered over with a kind of paſte or foil, that ſtrongly reflected the ſun's rays. But what their power was, he did not ſee.

immenſe body of fire, the ſun; a maſs wonderful, and worthy of its Maker, whether we conſider its immenſity, its exceſſive heat, or its abſolute neceſſity and great uſe to us, and to all the reſt of its ſyſtem. But we ſhall find yet farther evidences of the great Creator's work in the following chapter.

CHAP. II.

OF THE DUE POSITION AND DISTANCE OF THE SUN AND ITS PLANETS.

AS the infinite power and wiſdom of God appears in the appointment and make of the ſun, according to the preceding chapter; ſo in this I ſhall demonſtrate the ſame from the due poſition of the ſun among his planets, and his due diſtance from each of them.

Now here we may take it for granted, that the ſun is the fountain of the light and heat of all the planets, not only of the earth, but of the other planets, that move either about the ſun, or the earth: but whether the ſun be placed in the centre of its ſyſtem, or the earth be ſo, is of no great conſequence here to enquire. But I have all along ſuppoſed the former to be the moſt probable hypotheſis, and it ſeems to be ſtill more ſo, from the conſideration we are now upon concerning the community of its light and heat to all the planets. For ſince it is manifeſt that what light and heat the planets have, they receive from the ſun, it is far more likely that this their fountain of light and heat is placed in the common centre of them, and that they move round about it, rather than it about them.

But be it ſo, or not ſo, it is however very certain, that all the planets are placed at ſuch a due and proper diſtance from the ſun, that they receive the beneficial rays thereof in a due manner and proportion. There is no great reaſon to doubt of this, among the planets that are at greater or leſſer diſtances from the ſun than we, becauſe we find a noble and ſolemn apparatus anſwerable to their diſtances from the ſun, which I intend to ſpeak of hereafter. But as for our own terraqueous globe, we have ſufficient ſignals of the great care and counſel that have been uſed in the due poſition and diſtance thereof from the ſun. For as to its poſition to the ſun, I have heretofore ſhewn, that by the inclination of its axis, and its diurnal and periodical revolutions, all parts have a due ſhare of light and heat. And as for its diſtance, it is ſuch as not only prevents the danger of its interfering with the other globes, as I have formerly obſerved, but alſo it is duly adjuſted to the denſity of the earth and waters, and to the make and temper of our bodies, and of all other things here below. Had we been much nearer the ſun, our world would have been burnt up and waſted; the waters in the firſt place would have been all turned into vapours, and dried up; vegetation have ſoon ceaſed, and all things would have ſoon been waſted, if not burnt and conſumed. Or had we been not at ſo very great a diſtance, but only a little nearer the ſun than now we are, ſuppoſe a few thouſands of miles, ſtill the heat would be as the ſquare of the [t] diſtance; and conſequently too great, if not for the polar, yet for the æquatorial parts. And, on the contrary, had we been ſet at a greater diſtance from the ſun, ſo would the ſun's heat have been abated in proportion to the ſquare of that diſtance. And in this caſe, if the diſtance had been very great, we and all things muſt have been perpetually frozen up; or if it had been not ſo great, the world would have ſuffered by cold, the polar at leaſt; if the æquatorial parts could have eſcaped.

And in this caſe, when our globe ſhould thus be parched up with everlaſting heat, or be everlaſtingly frozen with exceſſive cold; inſtead of an

[t] Newton, Princip. p. 466.

an habitable, pleaſant, and comfortable world, it muſt become a deſart, a place of irkſomeneſs, miſery, and everlaſting puniſhment. But the great Creator having ſo wiſely and indulgently ordered the diſtance between the earth and ſun, the ſun's light and heat are incomparably accommodated to the ſtate and temper of all things here below, and our world is well fitted for habitation, well provided with every thing that may miniſter to the ſupport, the comfort, and pleaſure of its inhabitants. By thoſe indulgent rays, all things are enlightened, and we and all the reſt of the animal kingdom are enabled to diſpatch our buſineſs, to ſeek and provide our food, and to paſs from place to place, as our occaſions or pleaſures lead us. By its cheriſhing beams all things are warmed and comforted, vapours in ſome meaſure made to riſe for the forming of clouds and rain: trees and plants are enabled thereby to put on their verdure and gaiety, and to yield us the benefit and pleaſure of their grain and fruit. By the preſence of this great fountain of light and heat, we, and even nature too, is awake and excited; and by its abſence, grows torpid and dull: its abſence by night diſpoſes us to reſt and ſleep; and even vegetables too ſhut up their flowers then[u], and in a manner betake themſelves to reſt: and its abſence in winter, how doth it change the whole face of nature, diveſt vegetables of their gay attire, force animals to places of ſhelter and ſafeguard, and give an aſpect of melancholy and horror to all things!

Thus it is manifeſt, how wiſely and indulgently the great Creator hath provided for the good of our planet, by ſo critically adjuſting its poſition to, and its diſtance from the ſun, to the ſtate and temper of it and all things thereon. And although the reſt of the planets encompaſſing the ſun, are ſome of them near to, ſome of them farther from it, yet there is no great queſtion to be made, but the ſame wiſe Contriver hath made as good a proviſion for them as for us, either by contempering their denſity to their diſtance from the ſun, or by ſome other the wiſeſt and beſt courſe; as we have very juſt reaſon to ſuſpect, from that grand and ſolemn apparatus I ſhall ſpeak of, of ſecondary planets. Which leads me to conſider the proviſions made for the ſupply of the ſun's abſence, and its greater diſtance.

CHAP.

[u] See Phyſico-Theol. Bk. X. Note (*a*) page 130, vol. 2.

CHAP. III.

THE NECESSITY OF LIGHT, AND THE PROVISION FOR IT BY THE ATMOSPHERE.

BEFORE I come to the other planets, it will be convenient to confider how the fun's abfence is fupplied here upon the earth, as alfo, probably, how it is fupplied in her concomitant, the moon.

And firft as to the earth. Of fuch abfolute neceffity is light (not to mention heat) that our world could not well be in the leaft utterly without it, becaufe if there fhould be utter abfolute darknefs (befides the great inconveniences it might bring to vegetables, minerals, and every other fuch like part of the creation, befides this I fay) it would certainly put animals under an abfolute incapacity of performing their moft neceffary bufinefs, and acting in that office which the Divine Providence hath appointed them, although of greateſt uſe to themſelves, or the reſt of the world. Men, for inſtance, whoſe buſineſs and occaſions oftentimes neceſſitate them to borrow a part of the night; and all other animals, particularly ſuch whoſe ſafety, or temper, or conſtitution of parts (as of their eye, for inſtance, or ſome other parts) confine them to their dens and places of retirement and reſt by day, and are therefore in courſe compelled to ſeek their food, and wander about on their moſt neceſſary occaſions of life by night; all theſe, I ſay, would at once be cut off from one of the grand benefits of life, from acting that part they bear in the creation, during ſuch time as they ſhould be put into abſolute darkneſs. But to prevent this, the infinitely wiſe Contriver of the world hath made divers admirable proviſions, both in our own, and the other planets too. One proviſion which he hath made in our own globe, and I may add that of the moon alſo, is by encompaſſing both with an atmoſphere[v], which, among

[v] Mr. Huygens, in his Coſmotheor. p. 115. concludes the moon to have no air or atmoſphere, becauſe we ſee its limb ſo clearly and accurately defined, and becauſe he thought there are no ſeas or rivers in the moon. But he was miſtaken both in his concluſion and part of his premiſes. For in the ſolar eclipſe May 1, 1706, which in Switzerland was total, they could manifeſtly perceive the moon's atmoſphere, as may be ſeen in the accounts given in Philoſ. Tranſ. No,

among other grand uſes, miniſters very much to the propagation of light partly by reflecting the rays of light, to our eye, and partly refracting them, ſo as to make them viſible and uſeful to us, when otherwiſe they would not appear. Hence that whiteneſs and brightneſs[w] obſervable in the air by day; and hence the twilight, when the ſun is hidden under the horizon. The like to which is obſervable in the moon alſo, in that ſecondary, ruſty light which is ſeen in her eclipſes, and before and after her quarters.

No. 306. And ſince that, in the laſt total eclipſe of the ſun, on April 22, 1715, the moon's atmoſphere was very diſcernible, appearing in the form of a curious ring of vapours encompaſſing the moon all the time of total darkneſs. Of which ſee the accounts in the Philoſ. Tranſ. and Mr. Whiſton's.

[w] See Phyſico-Theol. Bk. I. Ch. i. Note (s) page 15. vol. 1.

CHAP.

CHAP. IV.

THE GREAT USEFULNESS OF THE MOON, AND THE MUTUAL BENEFICIAL RETURNS WHICH THE GLOBES MAKE TO ONE ANOTHER.

HAVING ſhewn the abſolute neceſſity of light and the ſupply thereof by the atmoſpheres; let us next ſpeak of the principal proviſion made for that, and for ſupplying the ſun's abſence; and that is by the moon and ſtars, which as Moſes ſaith [x], "rule the night, as the greater "light, the Sun, doth rule the day." What influences theſe celeſtial bodies may have here below in the bodies of men and other animals, or among vegetables, foſſils, or in any of the grand works of nature, is hard to determine, although vainly pretended unto by the judicial aſtrologers; but yet ſome things there are, whoſe periods and criſes ſo ſtrictly obſerve the courſes of the Sun, eſpecially of the Moon, that, on the other hand it

[x] Gen. i. 16.

it is hard to deny the influences of theſe bodies here below. The tides particularly have all along ſo conſtantly obſerved the courſes of the moon, that in all ages they have been ſuſpected to be cauſed and governed by that planet: and if the ſtories of Pliny [y], Ariſtotle, and others of the ancients, be true, it is by her influence, that the bodies of oyſters and other ſhell-fiſh are increaſed and diminiſhed: that the maſs of man's blood is ſo alſo; that the humours are reſolved and attracted; that the dead bodies of beaſts are corrupted; that all animals expire at the time of ebb, particularly man; that the ſea purgeth itſelf of filth every full-moon, which gave occaſion to the fable of the ſun's having his ſtable about Meſſina and Milazzo; and divers other ſuch like conceits which thoſe authors name, too many, and too improbable, to deſerve to be reckoned up in this place.

But whatever influences the moon may have upon things here below, whatever her concern may be in any tranſaction of nature, or any other office of the creation, it is however very certain, that her light, eclipſes, monthly revolutions, and latitude or vagations towards our poles, are of great uſe to us.

By

[y] Plin. Nat. Hiſt. L. ii. Ch. 41, 98, 99, 101.

By her light, to which I may add that of the ſtars, we and the reſt of the creatures are able to protract our day at pleaſure, to go hither and thither as our occaſions call, and to diſpatch many of our affairs by night, or to betake ourſelves to repoſe and reſt; to which, according to Pliny [a], the moon doth naturally incline us.

As to the eclipſes, whether of ſun or moon, they have their excellent uſes too. The aſtronomer applies them to conſiderable ſervices in his way; and the geographer makes them no leſs uſeful in his: the chronologer is enabled by them to amend his accounts of time, even of the moſt ancient days, and ſo down through all ages; and the mariner too can make them ſerviceable to his purpoſe, to diſcover his longitude, to correct his account at ſea, and thereby make himſelf more ſecure and ſafe in the untrodden paths of the deep.

So for the monthly revolutions of the moon, beſides the uſes they have in the daily variations of the tides, and perhaps cauſing ſome ſuch revolutions

[a] Ferunt Lunæ fœmineum ac molle ſidus, atque nocturnum, ſolvere humorem, & trahere, non auferre. Id manifeſtum eſſe quod——Somno ſoſpitis torporem contractum in caput revocet. Pliny; l. ii. c. 101.

volutions too in the humours and bodies of animals, and in the works of nature; besides this, I say, they are manifestly of excellent use in the divisions of time, in measuring out our months, as the sun doth our days and years, according to that appointment of the Creator, Gen. i. 14. "And God said, Let there be lights in the "firmament of the Heaven, to divide the day "from the night; and let them be for signs, and "for seasons, and for days, and years."

And lastly, as to the lunar latitude, or progresses towards our poles, besides the use hereof to the preventing the too frequent eclipses of the sun and moon, those vagations are of great use to the polar parts of the world, in affording them a longer, as also a stronger and better light than if the rays fell more oblique: which must needs be a very great comfort, and of wonderful service to the inhabitants of those forlorn parts, in their long and tedious nights, of some days, yea, some months length: to men, to enable them to dispatch such of their affairs as are of perpetual and constant necessity; and to other animals of the air, land, or waters, to enable them with greater ease and pleasure to get their food, and pass where their pleasure leads them.

Thus

Thus the great Creator hath made the moon to be of admirable ufe to our earth. And fo wifely hath he contrived his works, that they are mutually ferviceable to one another, fo that what good fervices one doth, the other as readily returneth again. Thus, as the moon is a moon to us, fo the earth is with great reafon concluded by the philofophers, to be a moon to the moon; not indeed a fecondary planet moving periodically about her, but fuch a planet, as reflects the light of the fun to her, and perhaps makes fuch like returns of influx, a as I faid the earth receives from her. For it is not to be doubted, if the earth reflects light, and gravitates to the moon, as well as the moon to the earth (which is highly probable), but that there is a mutual intercourfe and return of their influences, and good offices. And this is ftill more probable from the likenefs difcernible between the earth and the moon, which is a ftrong prefumption that the moon may have the fame occafions for the earth, as the earth for her. For that fhe is an opake body, and that her furface is covered in fome meafure with hills and valleys is manifeft beyond all doubt to our eye [a], as I before

[a] See Book v. chap. 2. note (r) p. 298.

before ſaid: and that ſhe hath an atmoſphere, is what hath been not long ſince [b] diſcovered: and that there are large oceans and collections of water, is what I have before made probable [c]. And therefore, agreeing thus in conſtitution and make, their occaſions for, and influences upon each other, are in all probability mutual, and much the ſame.

And after this manner, the infinitely wiſe Contriver of the univerſe ſeems to have tranſacted throughout that immenſe ſpace, by making all the ſeveral globes uſeful to one another. Thus all the planets of our ſolar ſyſtem are of conſiderable uſe to us, all of them reflect light unto us, and ſome of them a light ſo bright and ſtrong, as particularly Venus and Jupiter, that they are a good ſupply of the moon's abſence in the night, as well as the ſun's. Nay, the very ſecondaries (which I ſhall ſhew are of greateſt uſe to their primary planets) have their uſes too amongſt us; not only as being evident demonſtrations of the great works of God, but alſo in miniſtering to the diſcovery of the longitude of the moſt diſtant places

[b] See before chap. 3. note (v)

[c] Book v. chap. 4. note (e) as alſo the Preface.

places upon the earth. So for the fixt ſtars, which I have before ſhewn to be probably ſo many ſuns miniſtering to as many ſyſtems of planets; it is certain they are of great uſe to us in ſupplying the abſence of the ſun and moon by night. And there is no great doubt to be made, but that the like returns are made to them and their ſyſtems by our ſun. So that here we have an admirable oeconomy obſervable throughout all the viſible regions of the univerſe, in the natural aſſiſtances and returns which one globe affords the other, even at the greateſt diſtance.

CHAP.

CHAP. V.

OF THE MOONS, OR SECONDARY PLANETS IN GENERAL, WHICH ARE OBSERVED ABOUT SOME OF THE PRIMARY PLANETS.

HAVING taken a view of the methods which are ufed for the accomodating the Earth with light and heat, let us caft our eye to the reft of our Solar fyftem, and examine whether any thing of the like kind is to be found there. And here we fhall find a no lefs admirable fcene of the great Creator's care and wifdom, than we difcovered in the Earth and Moon. In Mars, indeed, we can difcern a great fimilitude with the Earth in its opacity and fpots, but we have not yet been able to perceive any attendance of Moons, as in the other fuperior planets; not fo much probably becaufe there are none, but becaufe they arc fmall, or they reflect a weak light, and are at a great diftance from us. And as for Venus and Mercury there may be no occcafion for any attendants, by reafon of their proximity to the Sun. But in the two higheſt or more diſtant planets, Jupiter and Saturn, we have a very noble and entertaining ſcene of the Creator's glory. For whereas thoſe two planets are at a much greater diſtance than any of the other planets, from their fountain of light and heat, the Sun; and as conſequently their heat and light are abated in proportion to the ſquare of their diſtances; ſo, to make them amends, they are ſurrounded with a more grand retinue of ſecondary planets, or Moons; Jupiter with four, Saturn with five, as it is imagined, and probably more [d].

And an admirable remedy this is, not only for the great diſtance of theſe two planets from the Sun, but alſo for the tardity of the periodick mo-

[d] Mr. Huygens, in his Coſmotheoros, p. 99. gives this account of the diſcovery of the ſatellites of Jupiter and Saturn. That it is well known the diſcovery of the circumjovials is owing to Galilæo; that the brighteſt, and outermoſt circumſaturnial he happened to ſee with a 12 foot glaſs in the year 1655: that the reſt are owing to Caſſini, who firſt ſaw them with a glaſs of Campani's grinding of 36 feet, and afterwards with one of as many feet above 100. That the 3d and 5th Caſſini ſhewed him in 1672, and afterwards oftener. That Caſſini acquainted him by letter afterwards with his diſcovery of the firſt and ſecond in 1684. That the two laſt are not eaſily diſcerned, and he cannot ſay he ever ſaw them. That beſides theſe five, he ſuſpects there may be one or more lye concealed. Of which ſee ch. vii. following.

motion in their refpective orbits. For whereas Saturn, revolves round the Sun but once in near thirty years, and Jupiter but once in near twelve, it comes to pafs that the places near the two poles of thofe planets have a night of near fifteen years in Saturn, and fix in Jupiter, fuppofing their axes inclined to the planes of their orbits, as it is in our own globe. But fuppofing (as it is imagined) that their axes are not fo much inclined, and that their days and night, their winters and fummers, are nearly equal; in this refpect the cafe would be worfe than in the long nights in the other cafe: but in both cafes the polar parts of both thofe planets would be difmal regions of darknefs, when fo long detained from the kindly vifits of the Sun. But an admirable remedy is found, and a glorious fcene of the great Creator's works appear therein, as will be manifeft by confidering particulars in each of thofe two fuperior planets.

CHAP. IV.

OF JUPITER'S MOONS, DAYS, AND SEASONS.

IN ſpeaking concerning the ſuperior planets in particular, I ſhall begin with Jupiter. The diſtance of this planet from the Sun is reckoned to be 343 millions of miles farther from the Sun than we are; and by that means the Sun's light and heat are 27 times leſs there than with us, and its apparent diameter five times leſs [e]. And conſidering how vaſt a globe Jupiter is, having its ſuperficies 100 times, yea, (according to Mr. Huygens's computations) 400 times bigger than that of the Earth; in this caſe, what vaſt tracts of that globe muſt needs lie in profound darkneſs and deſolation, had no remedy been provided! But there are divers provided. One is by the frequent rotations of Jupiter round its own axis; which being performed in leſs than ten hours, it comes to paſs, that

[e] Gregorii Aſtron. l. vi. Prop. 5. Mr. Huygens makes the light and heat but 25 times leſs, and the apparent diameter five times. Coſmoth. p. 103.

that what is wanting in the ſtrength and degree of light and heat, is compenſated by the frequent returns thereof.

The other remedy is by the increaſe of the number of Moons about Jupiter, who is attended (as I ſaid) with four, as we, who are nearer the Sun, are with one, Concerning which theſe four things are remarkable:

1. Their bulk, which in all probability is not in any of them leſs than our Earth, as the moſt ingenious Mr. Huygens concludes [f] from their ſhade upon Jupiter's diſk. By which means partly it is that,

2. They reflect ſo ſtrong, briſk, and vivid a light, as appears very illuſtrious and entertaining even to us at ſo great a diſtance from it: which cannot but be very pleaſing and comfortable to that planet: beſides the no leſs beneficial and friendly influences conveyed therewith at the ſame time.

3. Their due diſtances from Jupiter, and from one another; and their agreeable periodic revolutions,

[f] Coſmotheor. p. 101.

lutions, which I have formerly obferved [g] to be in the moft exact mathematical proportions. By the firft of thefe, thofe fatellites efcape all difagreeable concourfes and violent oppofitions, and in the moft kindly manner, fend their influx to the planet they wait upon: and by the latter, they are perpetually carrying about their light and other benefits from place to place. For by the motion of the innermoft round once in lefs than two days; of the next in about $3\frac{1}{2}$ days; of the third in fomewhat above a week; and of the outermoft in near 17 days: by thefe means, I fay, it happens very feldom, that any part of Jupiter is at any time without the prefence and attendance of one or more of thofe fatellites; but one is vifiting one part, whilft another is attending another: and another another part, and Jupiter himfelf making fpeedy returns and revolutions all the while.

4. The laft thing remarkable is, the latitudes of Jupiter's Moons, or their progreffes towards his poles, which are in a due proportion to their diftances and periods; as I have before fhewn, Book IV. Chap. v.

And

[g] Book IV. Chap. iv.

And as the latitudes of theſe ſatellites differ according to their diſtances and periods; ſo another remarkable thing therein, is, that they ſhift their latitudes in longer or ſhorter times, according as their latitudes or vagations towards the polar parts of Jupiter are greater or leſſer. By which means ſome are making their progreſſes towards Jupiter's poles one way, whilſt ſome are wandering the other way, and ſome are ſtaying there a longer time, and ſome a leſſer and leſſer time. By which quadruple variety of latitudes, and perpetual changes of it, it comes to paſs, that thoſe large tracts towards the polar parts of that vaſt planet, have their due ſhare in the light and kindly ſervices of its four Moons, and are ſeldom or never deprived of them.

CHAP. VII.

OF SATURN'S MOONS, RING, DAYS, AND SEASONS.

HAVING feen the admirable provifion made for the remedying Jupiter's great diftance from the Sun; let us, in the laft place, take a view of Saturn, which is above 200 millions of Englifh miles farther from the Sun than Jupiter, and near 700 millions of miles farther than is our Earth. And here our glaffes, as imperfect as they are, have difcovered fo furprizing an apparatus, that muft needs ftrike every one that views it with wonder and amazement.

For, in the firft place, inftead of four fatellites or moons, as Jupiter hath, Saturn hath five, and probably more. Three of thefe I myfelf have feen with Mr. Huygens's 120 foot glafs; but, for want of a pole of fufficient height to mount the glafs high enough, I am not fure I have feen any more. And befides thofe five, which others have feen, there is great reafon to conclude there is a fixth lying between the two outermoft, there being a larger fpace between them than is in proportion to what is found amongſt the reſt. And it is not improbable, but that there are others alſo lying beyond the fifth or outermoſt, but become inviſible at ſo great a diſtance from us, by means of ſome obſcurity ſuch as is obſervable in the outermoſt itſelf, which is never to be ſeen by us, but in the weſtern part of its orbit, as Mr. Huygens obſerves [h].

Theſe ſatellites we may reaſonably conclude to be of a prodigious bulk, for the reflecting of light, and for their other miniſtrations to Saturn, becauſe otherwiſe they could not be ſeen at ſo great a diſtance as the Earth; and particularly one of them [i] is of that magnitude, and its light ſo briſk and vivid, that it appears very illuſtrious through our longer glaſſes, and may be diſcerned with our ſhorter.

As

[h] The reaſon why Saturn's fifth ſatellite appears not on the eaſtern, but weſtern part of its orbit, Mr. Huygens very ſagaciouſly (like himſelf) conjectures to be, becauſe this ſatellite, as the Moon doth to the Earth, always turn one and the ſame ſide to Saturn, and becauſe this ſatellite hath, he imagines, only one part of its ſurface clear, and the greateſt part obſcure, and not able to reflect ſufficient light to us; therefore all the time that obſcure part is turned towards us (which is whilſt the ſatellite is in the eaſtern part of its orbit) it diſappears: but in the weſtern part it appears, becauſe the bright ſides lie towards us. Coſmotheor. 118.

[i] It is the fourth ſatellite, or outermoſt but one (called from its firſt dicoverer, the Huygenian ſatellite) that is ſo viſible.

As to the diſtances, the periods, and latitudes of thoſe ſatellites, they being conſentaneous to what I have already taken notice of in Jupiter, I ſhall not inſiſt upon them, but paſs to another proviſion made for the great diſtance of that planet; which is a thing ſo ſingular to Saturn, ſo unuſual in all the reſt of the creation, and ſo amazing, that it is an evident and noble demonſtration of the great Creator's art and care; and that is Saturn's ring. Concerning which theſe things are obſervable:

1. The prodigious ſize of it, its great breadth and vaſt compaſs. This we may make a judgment of, by comparing it with Saturn himſelf, and ſuppoſing the diameter of Saturn to be as is before determined, 93451 Engliſh miles; the diameter of his ring will be 210265 ſuch miles, and its breadth about 29200 [k], an amazing arch to an eye placed in that planet.

2. The due and convenient diſtance of it from Saturn itſelf; not cloſely adhering to it, becauſe that would annoy a large portion of Saturn's globe,

[k] Mr. Huygens, in his Syſtema Saturn. p. 47. and Coſmotheor. p. 109. determines the diameter of Saturn's ring to the diameter of Saturn, to be as nine to four; and the breadth of the ring, and diſtance of the ring from Saturn's body, to be nearly equal, and accordingly theſe numbers are defined here.

globe, by depriving it of the Sun's rays, but environing it about the diſtance of its breadth; by which means the Sun's light and heat are permitted to enter between the planet and its ring, whilſt other rays are at the ſame time reflected upon the planet by the ring.

3. The thickneſs of the ring, which is hardly if at all, perceivable by us; which is as great a benefit, as its edging ſhade would be annoyance, was the ring thick.

4. Its ſmoothneſs and aptitude to reflect light and heat[1] is a wonderful convenience in it. Was it full of mountains and valleys, and I may add waters too, as in our Earth, and probably the Moon likewiſe, the reflection would be too weak to render the ring viſible unto us, at ſo great a diſtance as we are; but perceiving its light to be ſo lively and ſtrong, as to render both itſelf and Saturn very illuſtrious, it is a demonſtration of the aptitude of its ſtructure, and ſmoothneſs for the reflection of light and heat to the planet it ſerves.

5. As the periodical revolutions of the Earth are an excellent and providential contrivance for thoſe

[1] See Huygens. Syſt. Saturn. p. 70.

thoſe uſeful and neceſſary mutations we have of the ſeaſons of the year, ſo no doubt but the ſame benefits accrue to thoſe revolutions which Saturn hath about the Sun. It is viſible, that as Saturn changes its place in its orbit, ſo its ring receives a variety of aſpects [m], not only with reſpect to us, but to the Sun. Thus in one part of the orbit it appears with a larger [n] ellipſis, ſo as to exhibit a larger ſpace between it and Saturn: in another part, with a leſſer, and ſo with a leſſer ellipſis, and ſometimes as only a ſlender ſtrait line, and ſometimes it is not viſible at all [o]: alſo ſome-

[m] Every 14 or 15 years Saturn's ring hath the ſame face; appearing at one time with large open anſæ, at another time with no ring at all. Which appearance is obtained by gentle progreſſes from the one to the other face. As, if the anſæ are the largeſt, they gradually diminiſh, until no anſæ, or apertures, are to be ſeen in the ring, and at laſt no ring at all alſo. See Fig. 8.

[n] This Mr. Huygens ſhews is when Saturn is 20 ¼ degrees in Gemini and Sagitary. This was the appearance it had in April 1708, and which it will again receive at the end of 1722; only with this difference, that whereas the ring traverſed the upper or northerly part of Saturn's diſk in 1708, it doth now, and will for ſome years to come, traverſe the lower or ſoutherly part thereof, as is repreſented in Fig. 7.

[o] Mr. Huygens ſhews, that for about ſix months before and after Saturn's being in 20 ¼ degrees of Virgo and Piſces, the ring is not viſible, but Saturn appears round. Syſt. Saturn. p. 59, 74, &c.

And

ſometimes one ſide of the ring is enlightened, and reflects light towards one part of Saturn, ſometimes the other enlightens another part; and there is no doubt, but that as our Earth has its ſeaſons, according to its poſition to the Sun in its periodical motion in its orbit; ſo Saturn throughout his period, hath his ſeaſons according unto his poſition to the Sun, and the various reflexions of the ring upon the ſeveral parts of his globe [p].

Theſe five things obſervable in Saturn's ring, we have pretty good aſſurance of, from our views through good glaſſes. But there is a 6th

And accordingly at this very time there is no appearance of the ring, only a ſmall narrow liſt or belt croſſeth the middle of Saturn's diſk, of a colour ſomewhat different from the reſt of Saturn's face, and in the place were the ring ſhould be. This appearance of Saturn is repreſented in Fig. 8. which is the appearance he had through a very good 34 foot glaſs, at the latter end of October and beginning of November this preſent year 1714. But a little before this, viz. on Sept. 26. I could through an 126 foot glaſs diſcern the narrow ends of the ring on each ſide Saturn. A repreſentation of which I have given in Fig. 9.

[p] There is a very great reaſon to imagine this doth certainly happen in Saturn, becauſe, as Mr. Huygens obſerves, Saturn appears ſometimes more ſplendid than at other times. *Ita ſemper* (ſaith he) *quo propius verſus Cancri & Capricorni ſigna acceſſerit, eo majorem, aut certe ſplendidiorem, etiam abſque teleſcopio appariturum, quippe annuli ellipſi ſemper ſe latius pandente.* Huygen. Syſt. Saturn, p. 56.

6th Thing I ſhall add as only conjectural, and that is, a ſuppoſition that the axis of Saturn [q] is inclined (and that pretty much alſo) to the plane of its ring, or the plane of its orbit at leaſt; and that he hath a diurnal rotation in ſome certain ſhort ſpace of time. For without theſe two conveniences, very large tracts of Saturn would ſuffer extremely for want of the Sun. For if Saturn hath no other motion but that round the Sun in its orb, one part muſt be excluded from the Sun's viſits for 15 years, whilſt the other partakes all the while of them; and one hemiſphere will enjoy the benefit of the ring, whilſt the other is eclipſed by it: and in this caſe the ring would be nearly as prejudicial to the eclipſed part, as it is uſeful to the enlightened. But ſuppoſing Saturn to move round in the ſame, or a ſhorter time than Jupiter, and in a path pretty much inclined to the ring, all parts then of that vaſt planet will have their frequent returns of day and night, of heat and cold. And ſince this is what is diſcernible in the other planets, and is no leſs neceſſary for the benefit and comfort of this, we may reaſonably conclude the thing to be probable, although not diſcernible at Saturn's great diſtance from us.

CHAP

[q] Mr. Huygens determines the inclination of Saturn's axis to the plane of his orbit to be 31 gr. as that of the Earth is 23 degrees. Coſmotheor. p. 108.

CHAP. VIII.

THE CONCLUSION.

THUS I have taken a view of the provifion made for thofe two grand, and univerfal neceffaries, light and heat; things, in all probability, no lefs neceffary for the other globes, than for our own: and things which not only animals cannot fubfift without, but what all things here below ftand in need of as well as they. When therefore we actually fee and feel thofe indulgent provifions, thofe amazing acts of the great Creator; when we have views of their extent into myriads of other the moft diftant globes; when (to go no farther) we fee in our own fyftem of the fun, fuch a prodigious mafs of fire as the fun is, placed in the centre, to fcatter away the darknefs, and to warm and cherifh us by day; and fuch a noble retinue of moons and ftars, attending and affifting us by night; when we fee this indulgence, this care of the Creator, extended to all the other planets, and that according to their feveral diftances, they have a proportionate provifion of the greater number of moons, and Saturn a ftupendous ring befides, to fupply the decreafe of light and heat; who can be otherwife than amazed at fuch providential, fuch ufeful, fuch well contrived, fuch ftately works of God! Who can view their glories, and partake of their beneficial influences, and at the fame time not adore the wifdom, and praife the kindnefs of their Contriver and Maker! But, above all, fhould there be any found, among rational Beings, fo ftupid, fo vile, fo infatuated with their vices, as to deny thefe works to be God's, and afcribe them to a neceffity of nature, or indeed a mere nothing, namely, chance! But fuch there are to be met with among ourfelves, and fome fuch the prophet tells us of, Ifai. v. 11, 12. Men that had fo debauched themfelves with drink, and enervated their minds by pleafures, that "they regarded not the work of "the Lord, neither confidered the operation of "his hands." Such perfons having led their lives in fuch a manner, as to wifh there was no God to call them to account, would then perfuade themfelves there is none; and therefore ftupidly afcribe thofe manifeft demonftrations of the infinite power and wifdom of God, to a mere nothing, rather than to their great Author. But may we not with as good reafon, imagine a light-

ed

ed candle, a well made culinary fire, a flaming beacon, or light-houſe, to be the work of chance, and not of man, as thoſe glories of the heavens not to be the works of God? For it is very certain, that as much wiſdom, art, and power worthy of God, is ſhewn in the lights of the heavens; as there is in thoſe upon earth, worthy of man, which none can doubt were contrived and made by man. And if from theſe mean contrivances and works of man, we conclude them to be the works of man; why not the grand, the amazing works of the heavens, ſurpaſſing all the wit and power of man; why not theſe, I ſay, the works of ſome Being as much ſuperior to man? According to the argument of Chryſippus, which ſhall conclude this Book: "If there be any Being that can effect thoſe things, which man, although endowed with reaſon, is not able to effect; that Being is certainly greater, and ſtronger, and wiſer than man. But man is not able to make the heavens; therefore the Being that did make them, excels man in art, counſel, prudence, and power."

BOOK VIII.

PRACTICAL INFERENCES

FROM THE FOREGOING

SURVEY.

IN the foregoing ſeven Books, having taken a view of what preſents itſelf to us in the heavens, and ſeen a ſcene of the greateſt grandeur, a work well contrived, admirably adapted, and every way full of magnificence; all that now remains is, to endeavour to make theſe views and conſiderations uſeful to ourſelves. Which I ſhall do in the following chapters.

CHAP. I.

THE EXISTENCE OF GOD COLLECTED BY THE HEATHENS FROM THE WORKS OF THE HEAVENS.

THE firſt and moſt ready and natural deduction we can make from ſuch a glorious ſcene of workmanſhip, as is before repreſented, is to conſider, who the great workman was?

That the author of all this glorious ſcene of things was God, is ſuch a concluſion, that even the moſt ignorant, and barbarous part of mankind have been able to make from the manifeſt ſignals viſible therein; ſignals ſo plain and concluſive, that Tully's Stoic [r] cites it as Ariſtotle's opinion, "That if there were ſuch a ſort of people, that had always lived under the earth, in good and ſplendid habitations, adorned with imagery and pictures, and furniſhed with all things that thoſe accounted happy abound with; and ſuppoſing that theſe people had never at any time gone out upon the earth, but only by report had

r D. Nat. Deor. L. ii. C. 37.

had heard there was ſuch a thing as a Deity, and a power of the gods; and that a certain time afterwards, the earth ſhould open, and this people get out of their hidden manſions into the places we inhabit; when on the ſudden they ſhould ſee the earth, the ſeas, and the heavens; perceive the magnitude of the clouds, and the force of the winds; behold the ſun, and its grandeur and beauty; and know its power in making the day, by diffuſing his light throughout the whole heavens; and when the night had overſpread the earth with darkneſs, they ſhould diſcern the whole heavens beſpread and adorned with ſtars, and ſee the variety of the moon's phaſes in her increaſe and decreaſe, together with the riſings and ſettings, and the ſtated and immutable courſes of all theſe throughout all eternity; this people, when they ſhould ſee all theſe things, would infallibly imagine that there are Gods, and that thoſe grand works were the works of the Gods." Thus have we the opinion and concluſion of two eminent heathens together, Ariſtotle, and Tully's Stoic.

And if the 'heavens ſo plainly declare the 'glory of God, and the firmament ſheweth his 'handy-work[s];' if thoſe characters, thoſe impreſſes

[s] Pſalm xix. 1, &c.

preſſes of the Divine hand, are ſo legible, that 'their line is gone out through all the earth, 'and their words to the end of the world, ſo that 'there is no language, tongue, or ſpeech where 'their voice is not heard;' nay, if theſe things are ſuch, that even a ſubterraneous people would at firſt ſight, conclude them to be God's work; how daring and impudent, how unworthy of a rational Being, is it, to deny theſe works to God, and aſcribe them to any thing, yea, a mere nothing, as chance is, rather than God? Tully's Stoic, laſt mentioned, denieth him to be a man who ſhould do this. His words[t] are, "Who would ſay he is a man, who when he ſhould behold the motion of the heavens to be ſo certain, and the orders of the ſtars ſo eſtabliſhed, and all things ſo well connected and adapted together, and deny that reaſon was here, and ſay theſe things were made by chance, which are managed with ſuch profound counſel, that with all our wit we are not able to fathom them? What! ſaith he, when we ſee a thing moved by ſome certain device, as a ſphere, the hours, and many things beſides; we make no doubt but that theſe are the works of reaſon. And ſo when we ſee the noble train of the heavens, moved and wheel-

[t] Cicero, ibid. cap. 38.

ed about, with an admirable pace, and in the moſt conſtant manner, making thoſe anniverſary changes, ſo neceſſary to the good and preſervation of all things; do we doubt whether theſe things are done by reaſon, yea, by ſome more excellent and divine reaſon? For, ſaith he, ſetting aſide the ſubtilties of diſputation, we may actually behold with our eyes, in ſome meaſure, the beauty of thoſe things which we aſſert are ordered by the Divine Providence." And then he enters into a long detail of particulars of this kind, too many to be named here.

Thus Cicero, throughout whoſe works ſo many paſſages of this nature occur, that it would be endleſs to cite them: and therefore one obſervation that ſhews what his opinion was of the ſenſe of mankind in the matter, ſhall cloſe what he ſaith, and that is in his Book de Legibus[w], where he ſaith, "Among all the tribes of animals, none but man hath any ſenſe of a God; and among mankind there is no nation ſo ſavage and barbarous, which although ignorant of what God it ought to have, yet well knows it ought to have one."

And

[w] L. i. chap. 8.

And after the ſame manner Seneca [v], who inſtanceth in two things to ſhew the deference we are apt to give to the general preſumption and conſent of mankind. One is in the immortality of the ſoul; the other is in the exiſtence of a Deity; which, ſaith he, " among other arguments we collect from the innate opinion which all men have of the Gods: for there is no nation in the world ſo void of law and morality, as not to believe but there are ſome Gods." Nay, ſo poſitive he is in this matter, that in another place he expreſsly ſaith, " they lie that ſay, they believe there is no God, for although by day they may affirm ſo to thee, yet by night they are to themſelves conſcious of the contrary." Much more could I cite out of this famous heathen; but one paſſage, relating to the Heavens, ſhall ſuffice, and that is in his diſcourſe, ſhewing, " Why evils befal good men, ſeeing there is a Divine Providence [w]," He takes it for granted in this diſcourſe, that there is ſuch a thing as a Divine Power and Providence governing the world; and he ſaith, " it was needleſs for him to ſhew that ſo great a work [as the world] could not ſtand without ſome ruler; that ſo regular

 motions

[v] Epiſt. 117.

re bonis viris, &c. c. 1.

motions of the ſtars could not be the effects of a fortuitous force, and that the impulſes of chance muſt be oftentimes diſturbed and joſtle; that this undiſturbed velocity, which bears the weight of ſo many things, in the earth and ſeas; ſo great a number of heavenly lights, both very illuſtrious, and alſo ſhining by a manifeſt diſpoſal, muſt needs proceed by the direction of ſome eternal law: that this can never be the order of ſtraggling matter; neither is it poſſible for things fortuitouſly and raſhly combined, to depend upon, and manifeſt ſo much art." Divers of which matters he proceeds to inſtance in. Thus Cicero and Seneca: to whoſe evidences I might have added many others, particularly a great deal out of Plato (the divine Plato, the Homer of philoſophers, as he is called by the ancients): but it would be needleſs, as well as tedious, ſince theſe two former have given us the ſenſe of mankind, as well as their own opinion in the matter.

CHAP.

CHAP. II.

GOD'S PERFECTIONS DEMONSTRATED BY HIS WORKS.

AS God's works have been ſhewn to be manifeſt demonſtrations of his exiſtence; ſo they are no leſs of his perfections, particularly of his infinite power, wiſdom, and goodneſs; inaſmuch as every workman is known by his work. A palace that ſhould have nothing defective in ſituaation, beauty, or convenience, would argue the architect to have been a man of ſagacity, and ſkilful in geometry, arithmetic, optics, and all other mathematical ſciences, ſerving to make a man a compleat architect; yea, to have ſome judgment in Phyſic, and natural philoſophy too. And ſo this glorious ſcene of God's works, the heavens, plainly demonſtrate the workman's infinite wiſdom to contrive, his omnipotency to make, and his infinite goodneſs, in being ſo indulgent to all the creatures, as to contrive and order all his works for their good. For what leſs than infinite could effect all thoſe grand things, which I have, in this difcourfe, fhewn to be manifeft in the heavens? What architect could build fuch vaft maffes, and fuch an innumerable company of them too, as I have fhewn the heavens do contain? What mathematician could fo exactly adjuft their diftances? What mechanic fo nicely adapt their motions, fo well contrive their figures, as in the very beft manner may ferve to their own confervation and benefit, and the convenience of the other globes alfo? What naturalift, what philofopher, could impregnate every globe, with a thing of that abfolute neceffity to its confervation, as that of gravity is? What optician, what chymift could ever have hit upon fuch a noble apparatus for light and heat, as the fun, the moon, and the ftars are? could amafs together fuch a pile of fire as the fun is? could appoint fuch lights as the moon and other fecondaries are? None certainly could do thefe things but God.

CHAP. III.

OF GOD'S RELATION TO US, AND THE DUTIES RESULTING FROM THENCE.

IT appearing from the laſt chapter how great a being the Creator is, it is time to conſider what relation he ſtands in to us, and what is due from us to him. His relation to us is that of Creator; and as ſuch, of conſervator, ſovereign lord, and ruler, one that hath an abſolute power over us, and all things belonging to us, that can ſubject us to what laws he ſees fit, and that can reward or puniſh us as we deſerve. And in this caſe, the leaſt we can do, is to revere and fear him at all times, to worſhip and ſerve him with all our power, to comply with his holy will ſincerely and heartily, and to obey him in all things he hath either forbidden, or enjoined. And conſidering alſo how great indulgence and love the Creator hath ſhewn in his works throughout the univerſe, it naturally follows that we ought to be truly thankful to him for his mercy

and

and kindneſs, and to love him for his love and goodneſs.

Theſe kind of concluſions are ſo natural, that the very heathens have in ſome meaſure made them. Thus Cicero's Stoic before cited [x], "*Quid vero? hominum ratio non, &c.* What! doth not man's reaſon penetrate as far as even the very heavens? For we alone of all animals have known the riſings, ſettings, and courſes of the ſtars: by mankind it is that the day, the month, and year, is determined; that the eclipſes of the ſun and moon are known, and foretold to all futurity; of which luminary they are, how great they will be, and when they are to happen. Which thing the mind contemplating, it receives from hence [y] the knowledge, of the Gods: from whence ariſes piety; to which is joined juſtice, and the other virtues; from which ſprings that bleſſed life, which is equal unto, and like that of the Gods themſelves, and in no reſpect yielding to thoſe celeſtials, except in immortality, which is not neceſſary to happy living." And in his

[x] De Nat. Deor, l. ii. c. 61.

[y] Some read it inſtead of accipit ad cognitionem Deorum; accipit ab his cognitionem Deorum.

his book De Legibus [a], Cicero brings in his collocutor ſaying, " *Sit igitur hoc a principio perſuaſum*, &c. i. e. Let this be what every member of the commonwealth is fully convinced of from the beginning, that the Gods are lords and governors of all things; that whatſoever things are done, they are managed by their influence, rule, and divinity; that they merit a great deal of mankind, and obſerve what every one is, what he doth, what he admits into his mind; with what mind, what piety he cultivates religion; and that they take an account both of the righteous and wicked. For, ſaith he, minds that are endued with theſe principles, will ſcarce ever depart from that opinion that is uſeful and true." And a little after [a], one of the laws ariſing from hence he ſaith is, " Let men approach the Gods with purity, let them practiſe piety; for he that doth otherwiſe God himſelf will be the avenger of." This purity and ſincerity is ſo neceſſary a concomitant of religion and divine worſhip, according to Cicero, that he makes it, in another place, to be that which diſtinguiſhes religion from ſuperſtition [b], " *Cultus autem Deorum eſt optimus*,

[a] Lib. ii. C. 7.

[a] Cap. 8.

[b] Nat. Deor. l. ii. c. 28.

mus, &c. But that religion, that worſhip of the Gods is the beſt, the pureſt, the holieſt and fulleſt of piety, that we always revere and worſhip them with a pure, upright, and undefiled mind and voice. For, ſaith he, not only the philoſophers, but our forefathers, have diſtinguiſhed ſuperſtition from our religion!" which he aſſigns the difference of, and then tells us, "that the one hath the name of a vice, and the other of praiſe."

Thus, as the heathens have, by the light of nature, deduced the exiſtence and attributes of God from his works, and particularly thoſe of the heavens; ſo have they, at the ſame time, collected what the principal duties are, which men owe to God; ſo reaſonable, ſo natural, ſo manifeſt they are to all mankind.

CHAP.

CHAP. IV.

LACTANTIUS HIS ARGUMENT AGAINST THE HEATHEN GODS.

THE next inference ſhall be one made by the eloquent Lactantius [c]: "*Argumentum illud quo colligunt univerſa cœleſtia Deos eſſe, &c.* i. e. That argument whereby they conclude the heavenly bodies to be Gods, proveth the contrary: for if therefore they think them to be Gods, becauſe they have ſuch certain and well contrived rational courſes, they err. For from hence it appears that they are not Gods, becauſe they are not able to wander out of thoſe paths that are preſcribed them: whereas, if they were Gods, they would go here and there, and every where, without any compulſion, like as animals upon the earth do; whoſe wills being free, they wander hither and thither, as they liſt, and go whitherſoever their minds carry them."

Thus

[c] Inſtitut. L. ii. c. 5.

Thus Lactantius, with great reaſon, refutes the divinity of the heavenly bodies; which, on the contrary, are ſo far from being Gods, and objects of divine honour and worſhip, that ſome of them have been taken to be places of torment. Thus comets particularly, which muſt needs have a very unequal and uncomfortable temper of heat and cold, by reaſon of their prodigiouſly near approaches to the ſun, and as great receſſes from it. Thus, according to the before commended Sir Iſaac Newton's [d] computation, the comet in 1680, in its perihelion, was above 166 times nearer the ſun than the earth is; and conſequently its heat was then 28,000 times greater than that of ſummer: ſo that a ball of iron as big as the earth heated by it, would hardly become cool in 50,000 years. Such a place therefore, if deſigned for habitation, may be imagined to be deſtined rather for a place of torment, than any other ſort of living.

But above all, the ſun itſelf, the great object of heathen worſhip, is, by ſome of our own learned countrymen, ſuppoſed to be probably the place of hell. Of which Mr. Swinden hath written a treatiſe called, An Enquiry into the Nature and Place of Hell.

CHAP.

[d] Principia, page 446.

CHAP. V.

THIS SURVEY OF THE HEAVENS TEACHES US NOT TO OVERVALUE THE WORLD; WITH REFLECTIONS OF THE HEATHEN WRITERS THEREUPON.

FROM the confideration of the prodigious magnitude and multitude of the heavenly bodies, and the far more noble furniture and retinue which fome of them have more than we, we may learn not to overvalue this world, not to fet our hearts to much upon it, or upon any of its riches, honours, or pleafures. For what is all our globe but a point, a trifle to the univerfe! a ball not fo much as vifible among the greateft part of the heavens, namely, the fixed ftars. And if magnitude or retinue may dignify a planet, Saturn and Jupiter may claim the preference: or if proximity to the moft magnificent globe of all the fyftem, to the fountain of light and heat, to the centre, can honour and aggrandize a planet, then Mercury and Venus can claim that dignity. If therefore our world be one of the inferior parts of our syſtem, why ſhould we unjuſtly graſp at it, and be guilty of theft or rapine, lying or cheating, or any injuſtice, or ſin for it? Why ſhould we ſacrifice our innocence for it, or part even only with a good name for it, which Solomon ſaith [e] "is rather to be choſen "than great riches!" Why ſhould we do thus, if we were ſure of gaining the whole terraqueous globe, much leſs do it for a ſmall pittance of it, as the beſt empire in the world is? For as our bleſſed Saviour argues, Matt. xvi. 26. "What "is a man profited, if he ſhould gain the whole "world, and loſe his own ſoul? or what ſhall a "man give in exchange for his ſoul?"

But paſſing over the arguments which Chriſtianity ſuggeſts, let us ſee how ſome of the heathen writers deſcant upon this ſubject. Pliny [f] is very pathetical in his reflections, when he had ſhewn what little portions of the earth were left for us, and what large tracts were rendered (as he thought) uſeleſs, the frigid zones being frozen up with exceſſive cold, the torrid zone being burnt up (as the opinion then was) with as exceſſive heat, and other parts drowned by the ſea, lakes, and

[e] Prov. xxii. 1.

[f] Nat. Hiſt. L. ii. c. 68.

and rivers, and others covered with large woods, desarts, or barren mountains: he then exclaims thus, "*Hæ tot portiones terræ,*" *&c.* i. e. These little parcels of land, which are left for our habitation; yea, as many have taught, this point of the world (for no other is the earth in respect of the universe) this is the matter, this the seat of our glory: here it is we bear our honours; here we exercise our authority; here we covet riches; here mankind make a bustle; here we begin our civil wars, and soften the earth with mutual slaughters." And then having shewn how by fraud and violence men strive to enlarge their estates, saith he, "What a little part of those lands doth he enjoy? And when he hath augmented them, even to the measure of his avarice, what a poor pittance is it that his dead body at last possesseth?" Thus Pliny. And after the same manner Seneca reflects upon the matter[g], when he shews how virtue tends to make a man compleatly happy; among other things, by preparing him for the society of God, by enabling the mind to soar above the things here below, and to make him laugh at the costly pavements of the rich, yea, the whole earth with all its wealth. "*Nec enim potest,* saith he, *ante contem-*

 nere

[g] Nat. Quæst. L. 1. Præf.

nere porticus," &c. i. e. A man can never be able to flight the ftately piazza, the noble roofs fhining with ivory, the curioufly clipped woods, and the pleafant rivulets conveyed to the houfes, untill he hath furveyed the whole world, and fpying from above our little globe of earth, covered in a great meafure by the fea; and where it is not, is far and near fqualid, and either parched with heat, or frozen with cold, he faith to himfelf, is this that point, which by fire and fword is divided among fo many nations? O how ridiculous are the bounds of mortals! The Ifter bounds the Dacians, the Strymon the Thracians, Euphrates, the Parthians, the Danube parteth the Sarmatians and Romans, the Rhine gives bounds to Germany, the Pyrenees to France and Spain, and between Ægypt and Æthiopia lie the vaft uncultivated fandy defarts. If any could give human underftanding to ants, would not they too divide their mole-hill into divers provinces?" And when thou lifteft up thyfelf in thy truly great province, and fhalt fee the armed hofts paffing here, and pofting there, as if fome great matter was to be acted, confider that this is no more than the running of ants in a mole-hill. For what difference between them and us, but only the meafure of a little body? That is but a point in which thou faileft, in which thou wageft war, in which thou difpofeft of kingdoms. But above there are vaft fpaces, to whofe poffeffion the mind is admitted, provided it brings but little of the body along with it, that it is purged of every vile thing, and that it is nimble and free, and content with fmall matters. And fo he goes on to fhew, that when the mind is once arrived to thofe celeftial regions, how it is come to its proper habitation; is delivered from its bonds; hath this argument of its divinity, that divine things delight and pleafe it, and is converfant with them as its own; that it can fecurely behold the rifings and fettings and various courfes of the ftars; that it curioufly pries into all thofe matters, as nearly appertaining to itfelf; that then it contemns the narrow bounds of its former habitation, it being but a trifling fpace, of a few days journey from the utmoft limits of Spain to the very Indies; where as the celeftial regions afford a path for the wandering of the fwifteft ftar for thirty years, without any refiftance; in which regions he tells us the mind arrives to the knowledge of thofe things at laft, which it had before long enquired after, and there begins to know God. Thus Seneca; which fhall fuffice for this third inference.

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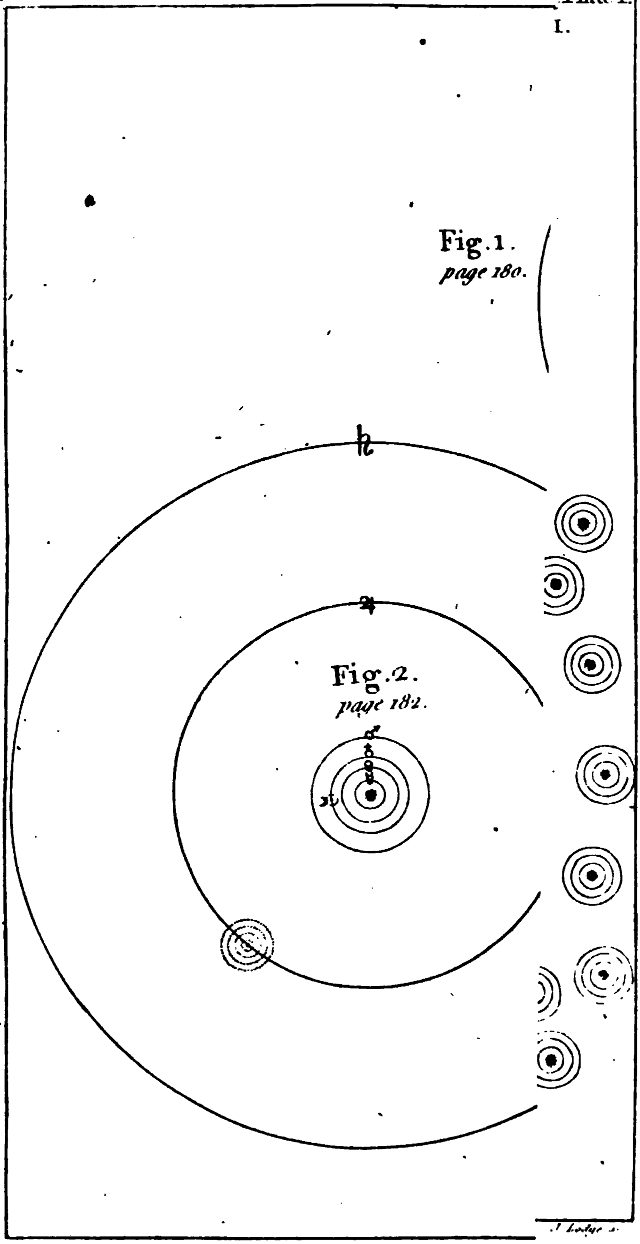

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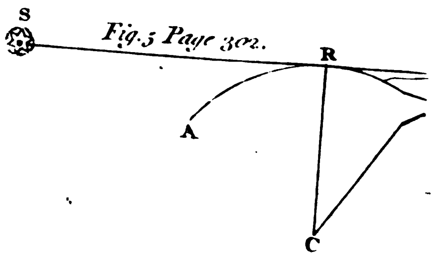

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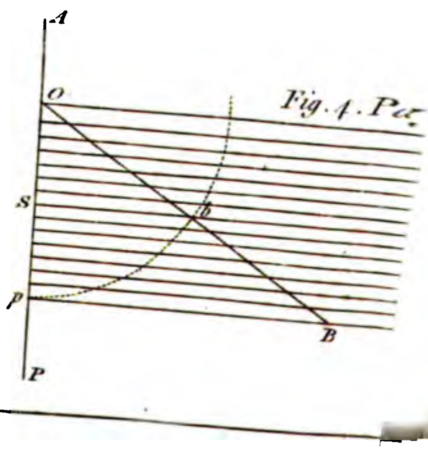

Fig. 4. Pa